The Incidence and Economic Burden of Hospital Acquired Infection occurring in Surgical Patients

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ABSTRACT

Background: Approximately 9% of patients in hospital have a hospital acquired infection (HAI). These infections place a burden on the health sector, patients and carers.

Objectives: To assess the incidence of, and independent risk factors for HAIs occurring in adult surgical patients; to assess the impact of these infections on the hospital sector; and to show how this information may be used to assess the potential benefits of prevention.

Design: A prospective survey of the incidence of HAI was conducted. Resources used by both infected and uninfected patients were recorded and costed. Generalised linear modelling techniques were used to estimate the impact of HAI on the observed variation in costs. Logistic regression analysis was used to determine independent risk factors for HAI.

Setting: A district general hospital in England

Subjects: 2469 adult patients admitted to five surgical specialties between April 1994 and May 1995.

Results: 7.5% (95% CI: 6.4, 8.6) acquired one or more HAIs that presented during the in-patient period. The incidence, economic impact and independent risk factors varied with site of infection. On average HAIs increased hospital costs by a factor of 2.3 (95% CI: 2.0, 3.0), equivalent to an additional £2,254 (95% CI: £1,738, £2,770) per case and increased length of stay by a factor of 2.1 (95% CI: 1.8, 2.5), equivalent to an extra 7.8 days (95% CI: 5.7, 10.0) per case. The estimates represent the average gross benefits of prevention. Net benefits depend on the cost and effectiveness of prevention activities. Estimates of the gross benefits of a 15% reduction in infection rates and a framework for assessing the net benefits of prevention are presented.

Conclusion: The study provides an estimate of HAI by specialty and site for surgical patients. It calculates the burden on the hospital sector and shows the benefits that might accrue if HAI rates were reduced.

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Plowman R, Graves N, Griffin M, Roberts JA, Swan AV, Cookson B, *et al.* The rate and cost of hospital acquired infections occurring in patients admitted to selected specialties of a district general hospital in England and the national burden imposed. *Journal of Hospital Infection* 2001;47(3):198-209.

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ABBREVIATIONS

ASA	American Society of Anaesthesiologists scores
BMI	Body mass index
BSI	Bloodstream infection
CDC	Centre for Disease Control
CI	Confidence interval
COI	Cost of illness
DGH	District general hospital
HAI	Hospital acquired infection
HICC	Hospital Infection Control Committee
ICU	Intensive care unit
ICN	Infection control nurse
ICT	Infection control team
IR	Infection rate
LOS	Length of stay
LRTI	Lower respiratory tract infection
OPCS	Office of population censuses and surveys
OR	Odds ratio
PAS	Patient administration system
RCT	Randomised controlled trial
SENIC	Study of the efficacy of nosocomial infection control
SWI	Surgical wound infection
UTI	Urinary tract infection

CHAPTER 1

INTRODUCTION

1.1 Introduction

Hospital acquired infections (HAI) are infections that are acquired during a patient's hospital stay. They are not a new problem; however, in recent years there has perhaps been greater awareness of the scale of the problem and the health and economic consequences that result from HAI.

In the UK, the issue of HAI has been the subject of a number of research studies conducted over the past few years, including the research on which this thesis is based.[1-3]

In 1992 the Department of Health commissioned the Public Health Laboratory Service to conduct an audit of infection rates, and infection control polices and practices in 19 hospitals in England and Wales, the results of which were published in 1997.[1] The audit drew attention to the problem of HAI, and highlighted considerable variation in infection rates occurring in similar patients treated in similar settings, and variations in infection control policies and practices.

At the same time the Department of Health commissioned the Public Health Laboratory Service and the London School of Hygiene and Tropical Medicine to conduct a study of the socio-economic burden of HAI. The results of this work were published in January 2000 and are reported in some detail in Chapter 4 of this thesis. The research drew attention to the substantial burden these infections place on scarce health sector resources and on patients and their carers.[2]

This work was used a little later in 1998 by the National Audit Office in their study of HAI. The study examined a number of issues including the scale of the problem, the rise of antibiotic resistance, the level of resources allocated to infection control within NHS Trusts in England, the resources available to infection control teams, and the potential benefits of investment in infection control practices. The results were published in February 2000.[3] The results were important in that they again served to highlight the very real problem of infection in hospitals, and the apparent lack of resources available to infection control teams to deal with the problem. The report was presented to the Parliamentary Select Committee of Public Accounts and the subject of a hearing in March 2000, following which a report was issued.[4] This served to further raise the profile of the problem of HAI, bringing it to the attention of the government, policy makers, health care professionals and the general public. In response the Department of Health has introduced a number of policy initiatives aimed at strengthening infection prevention and control activities within the NHS.[5]

1.2 The scale of the problem

Prevalence studies conducted in England and Wales in 1980[6] and again in 1993/94[7] found that at any one time an estimated 9% of hospital in-patients had an infection that they had acquired after admission. At the same time, it is likely that many more patients discharged from hospital had an infection related to a recent hospital admission. More recently the study of the socio-economic burden of HAI estimated that at least 321,000 patients admitted to NHS hospitals in England acquired one or more HAIs in 1994/5.[8] This estimate is based on the incidence of HAI observed in the study and relates to the number of infections occurring in adult non-day case patients admitted to the medical and surgical specialties covered in the study at NHS hospitals in England (an estimated 70% of adult non-day case admissions), and is further limited to infections which present during the in-patient period. Thus the actual number of patients acquiring one or more HAIs is likely to be considerably higher.

1.3 The impact of HAI on the individual

The acquisition of an infection in hospital may have health and financial consequences for affected patients. The impact on health status and recovery will vary considerably from one patient to another depending on the type of infection acquired, the underlying health status of the patient, the effectiveness of treatment given and how these various factors interact. For example, in some cases the impact may be limited to minor discomfort, but in other cases the acquisition of an infection may prolong recovery, cause temporary or permanent disability and may directly cause or substantially contribute to a patient's death. An estimated 5000 deaths every year are thought to be directly caused by an infection acquired in hospital, and HAIs are thought to contribute to a further 15,000 deaths.[9]

In terms of the economic consequences for the individual, acquiring an infection in hospital may result in an increase in out of pocket expenditure on health related items, and a reduction in income due to a delayed return to employment or in some cases the failure to return to employment. Few studies have estimated the magnitude of these costs. Some notable exceptions include a study by Farbry *et al* (1982)[10] that indicated surgical wound infections (SWIs) delayed return to work, and the study on which this thesis is based which assessed the impact HAIs had on both patients and their carers. [2]

1.4 The impact on the health sector

The acquisition of an infection in hospital may result in the additional use of hospital and primary health care resources. Additional hospital costs may result from an increased need for investigations and procedures, increased dispensary demands, additional nursing and medical care and a prolonged in-patient stay. Following discharge, patients who have acquired an infection in hospital may require a greater number of hospital appointments, and/or appointments with primary health professionals, including general practitioners, practice nurses and district nurses, than they would have required in the absence of an infection.

A number of studies have assessed the economic burden HAIs place on the health sector. These studies vary in scope. The majority concentrate on the cost to the hospital sector resulting from increased in-patient care, and relatively few look at costs to the health sector post-discharge. The types of infections included vary, some focussing on all types of HAI occurring in selected patient groups, while others focus on a specific type of infection. The methods used to identify, measure and value resources used and attribute them to HAIs also vary, as do the estimates derived. However, despite variations in scope and the methods employed all point to the substantial burden these infections place on health sector resources. The socio-economic burden of HAI study estimated that HAIs cost the health sector in England at least £1 billion in 1994/5.[2]

1.5 Why patients acquire an infection

Infection occurs as a result of complex interactions between potential pathogens (bacteria, virus, fungus or protozoan) and the host, in this case the patient. Within the hospital environment patients are at particular risk of infections. Patients whose primary illness compromises their immune system, such as AIDS and various forms of haematological malignancy, are particularly susceptible, as are the young and the elderly. Treatment regimens, such as chemotherapy, will also render a patient susceptible to infection and invasive procedures including operative procedures, and the insertion of intravenous and intra-arterial catheters, urinary catheters and endo-tracheal tubes offer direct access for micro-organisms. In addition the patients normal flora is frequently replaced with hospital flora that is often resistant to antibiotics and so may set up a potential source of infection.

1.6 The scope for prevention

Whilst not all HAIs are preventable the evidence indicates that a proportion of infections can be prevented through improvements in infection prevention and control activities. The early results from the National Nosocomial Infection Surveillance Scheme provided strong evidence that this is the case. Infection rates occurring in patients who had specific surgical procedures were found to

vary markedly from one hospital to another and the observed variation in rates continued to be present after adjustment for case mix differences had been made.[5] These results suggest that the variation observed to some extent reflected differences in clinical practice and serve to highlight the potential for a reduction in infection rates.

Quantifying the level of infections that can be prevented is difficult: it is difficult to quantify an event that does not occur. The most frequently quoted estimate, taken from the results of a comprehensive study conducted in the US (the Study of the Efficacy of Nosocomial Infection Control - SENIC), suggests that 30% of HAIs could be prevented.[11] However, caution should be exercised before applying this estimate to infections occurring in the UK. The estimate was derived from a study conducted over 20 years ago in the US. Since that time there have been many changes in the treatments and care options offered, and the case mix of patients treated. As such there may be important differences in the risk profile of patients treated today, compared to that of over 20 years ago. Nevertheless the results demonstrated that there is scope for a reduction in rates.

The results of a National Audit Office survey of NHS hospitals in England, documented in their report 'The Management and Control of Hospital Acquired Infections in Acute NHS Trusts in England' published in 2000, further highlight the fact that there is scope for a reduction in infection rates.[3] As part of their survey, infection control teams (ICTs) were asked what proportion of infections they believed could be prevented. The responses ranged from 5% to 40%. The responses were subsequently weighted by the number of beds in the responders' hospitals and a 'bed weighted' average of 15% derived. Whilst this is somewhat less than the US estimate, it does serve to highlight the belief that prevention is to some extent possible, whilst the exact proportion that is preventable remains unknown.

1.7 The potential benefits of improved prevention

Quantifying the benefits of prevention is difficult. Difficulties are associated with both identifying and valuing infections averted. It is difficult to measure the benefits of an event that did not take place. However, estimates derived from the results of the socio-economic study suggest that the benefits of prevention are likely to be substantial.[2] This point was highlighted recently in the NAO report, which estimated that if a 15% reduction in rates could be achieved this could lead to the release of health sector resources valued at £150 million per annum.[3] It should be stressed that this estimate reflects the value of resources, which might be released for alternative use. It does not represent potential cash savings. However, given that the NHS is working above capacity in most sectors HAIs have an opportunity cost. The estimates represent the gross benefits of prevention. Net benefits will depend on the cost of interventions introduced to achieve such a reduction.

1.8 The rationale for this thesis and the anticipated contribution it will make

At the time of undertaking this thesis relatively little was known about the cost of HAIs to the health sector in England. It was clear from the results of the 1980 National prevalence study that HAIs affected a large number of patients every year: 9.2% of patients at any one time were found to be affected in 1980.[6] However, data on the magnitude of the economic burden these infections imposed on the health sector, and indeed on patients and carers were lacking. Data from a number of international studies, and in particular the results of work stemming from the SENIC study conducted in the US indicated that HAIs were likely to be placing a substantial burden on limited NHS resources and on patients and carers. Estimates suggested that HAI cost the health sector in the US at least $4 billion per annum in 1985.[12] Whilst studies had been conducted in the UK,[13] [14] these were either relatively small, or rather specific in nature relating to particular patient groups, and were undertaken some years ago. A more comprehensive estimate of the magnitude of the burden of HAI was needed. The only national estimates available at the time were an estimate derived by the Department of Health which, based on a number of broad

assumptions, estimated that HAIs cost the health sector £111 million per annum,[15] and an estimate derived by Coello *et al*[14] which indicated that HAIs occurring in surgical patients cost the health sector in England an estimated £170 million in 1993.

It was against this background, and in the knowledge that a proportion of HAIs were preventable, that the Department of Health in October 1992 commissioned a study of the socio-economic burden of HAI. This thesis is based on this study. The socio-economic burden study aimed to provide a comprehensive assessment of the costs resulting from HAIs occurring in adult, non-day case patients admitted to specialties that are common to most hospitals. This was to include costs to the health sector as a result of additional in-patient care, costs to the health sector arising post-discharge and costs to patients and carers. It was anticipated that the results would raise awareness of the magnitude of the burden of HAIs, and the potential gross savings that might result from improved prevention and control. Through this process it was hoped that a greater understanding of the economic burden resulting from these infections would be gained, and that the information generated would assist in policy formation and inform clinical practice in relation to infection prevention and control. Further details about this study are presented in Chapter 4.

This thesis is closely linked with the socio-economic burden of HAI study. It focuses on a sub-section of data relating to adult non-day case surgical patients. The thesis assesses the incidence and economic impact that HAIs that present during the patient's hospital stay have on the hospital sector as a result of additional in-patient care. It also explores possible risk factors for these infections and considers how the information derived may be used to demonstrate the potential benefits of investment in prevention and inform prevention strategies.

Surgical patients were selected as the population of interest as it was felt that it would be interesting and beneficial to explore in greater detail the incidence and impact of HAIs occurring in this patient group. The underlying study assessed the incidence and economic burden of HAIs occurring in patients admitted to selected medical and surgical specialties taken together, and also the incidence and burden of infections occurring in patients admitted to each medical and surgical specialty. No attempt was made to assess the incidence and economic burden of HAIs occurring in patients admitted to surgical specialties taken together. A further reason for selecting surgical patients was an interest in exploring risk factors for infections in this patient group.

As indicated above this thesis focuses on the incidence of HAIs presenting during the in-patient period and the economic impact that HAIs had on the hospital sector as a result of additional in-patient care. The decision to focus on infections that presented during the in-patient period, and their impact on the hospital sector was informed by the results and inherent limitations of the earlier study.

Estimates of the incidence of infections presenting post-discharge, derived in the earlier study, were based on the responses given to specific questions within a detailed questionnaire sent to a proportion (approximately one third) of patients one month post-discharge. The estimates derived indicated that a proportion of patients experienced symptoms suggestive of a surgical wound, urinary and/or respiratory tract infection. However, it was not possible to say whether the symptoms reported represented actual infections, or whether the infection, if present, was hospital acquired. Furthermore, since only a small proportion of patients were followed up there was considerable uncertainty surrounding some of the estimates derived and it was clear that there were insufficient data available to allow for further analysis limited to a subset of data relating to surgical patients from which estimates could be derived with a degree of certainty.

Similarly, whilst the underlying study's estimates of the impact HAIs had on hospital costs as a result of additional in-patient care were based on data on the hospital costs incurred by all study participants, estimates of the costs falling on the primary health care sector, patients and carers were only derived for a proportion of patients. The results of the analysis of the impact HAIs had on these other areas of costs clearly showed that HAIs imposed a burden on the primary sector, patients and carers. However, as with the estimates of the incidence of HAI presenting post-discharge, there was considerable uncertainty surrounding some of the estimates derived and it was again clear from the results derived that there were insufficient data available to allow for further analysis limited to surgical patients from which estimates could be derived with a degree of certainty.

Similar reasons informed the decision not to examine the impact HAIs occurring in surgical patients had on health status. The underlying study's assessment of the impact HAIs had on health status was based on an analysis of responses given to the SF-36, included as part of the questionnaire, administered to a proportion of patients post-discharge. The results of this analysis indicated that HAIs had a negative impact on health status as measured by this instrument. However, again there was uncertainty surrounding the estimates derived and it was clear that there were insufficient data available to justify further analysis limited to a subset of data relating to surgical patients from which robust estimates could be derived.

The thesis aims to add to the findings of the socio-economic burden study by providing a more detailed account of the incidence of HAIs occurring in this patient group than presented in the underlying study report and, through the use of slightly different methodology, explore the economic burden these infections place on the hospital sector in more detail. It is hoped that this piece of work will further contribute to our understanding of the economic burden these infections impose, how costs can be attributed to infection and possible risk factors for infection. The thesis will subsequently show how information on the

economic burden imposed by these infections might be used to demonstrate the benefits of investment in infection prevention and control and how information on costs and possible risk factors can be combined and used to inform policy and practice.

1.9 My role in the socio-economic burden study

In September 1993 I was appointed project leader for the socio-economic burden of HAI study. As project leader I was responsible for the day to day management of the project, developing and implementing the outline protocol, and writing up and disseminating the results of the study. During the course of the study my role included a wide range of activities summarised below.

1.9.1 Literature review

On appointment I conducted a review of the literature on the epidemiology and economic burden of HAI. This review was updated at regular intervals throughout the course of the study.

1.9.2 Establishing links with staff at the study hospital

At an early stage I established links with staff at the study hospital including the chief executive, director of clinical practice, director of nursing practice, clinical directors, business managers, senior nurse managers, nursing staff on each of the study wards, consultants and their medical teams, laboratory staff, members of the infection control team and infection control committee, general practitioners, primary health care managers, district nurse patch managers and staff from the medical records, medical coding, finance and information technology departments. This involved writing to selected individuals, setting up a meeting and subsequently meeting with staff to discuss the aims and objectives of the study and the methods to be employed. The majority of these meetings were on a one to one basis. However, when both appropriate and possible, group meetings and seminars were held. This latter approach was particularly useful when informing ward staff of the project.

1.9.3 Further development and implementation of the study protocol

As project leader I was responsible for the further development and implementation of the study protocol. This included the development of patient and relative information sheets, consent forms, procedures for recruiting patients into the study, and appropriate data collection methods. The latter included the development of data collection sheets and patient questionnaires. This was done in consultation with members of the steering and advisory groups, other researchers and where appropriate members of the study hospital staff. Procedures for recruitment and data collection were written up and circulated to steering group and advisory group members for comment and subsequent approval, together with patient and relative information sheets and consent forms and all other data collection forms.

1.9.4 Selection and implementation of an appropriate data entry system

It was clear from the outset that the data requirements of this study were considerable. As project leader I was responsible for investigating the various data entry systems available and presenting the options to the steering committee, together with recommendations as to which would be most appropriate and why. A variety of systems were explored including paper questionnaires, and subsequent data entry either by project staff or a data entry company; the use of hand held computers; and the use of scanning software developed by Formic Ltd. After a thorough investigation of a number of options, the latter system was selected and purchased. I was subsequently responsible for setting up the scanning data entry system. This involved creating questionnaires and data collection surveys with the scanning software, setting up each individual question within the questionnaire ready for scanning and subsequently testing the scanning process. Testing involved checking that the forms were being read correctly and that the process was reliable. This proved to be a very time consuming process. There were a number of problems with the early versions of the software that had to be corrected by the software

manufacturer. This process led to delays in the development of the data collection forms and used a considerable amount of my time.

1.9.5 Obtaining the approval of the relevant ethical committees prior to the pilot study

As project leader I was responsible for submitting all relevant documentation to the ethical committee at the study hospital for their consideration, and subsequently responding to any queries that they had.

1.9.6 Conducting a pilot study and revising the methods in response to the findings of the pilot study

As project leader I was responsible for piloting the proposed methods. A small pilot study was conducted. This identified a number of problems with the draft data collection sheets and the proposed methods. A report was drafted and presented to the steering committee together with recommendations for changes and revisions to the data collection methods and data collection tools. Changes were agreed and subsequently made to the relevant forms and procedures. A report summarising the outcome of the pilot study, was subsequently presented to the Advisory Committee.

1.9.7 Re-submitting the study protocol and data collection forms for ethical approval prior to the main study

Following the pilot study the protocol and data collection forms had to be re-submitted to the study hospital ethical review committee for their consideration prior to the main study. As project leader I was responsible for this process and for responding to any subsequent queries that they had.

1.9.8 Recruiting and training six research assistants

As project leader I was responsible for the recruitment and training of six research assistants. Five research assistants were appointed in January 1994 and a further research assistant was appointed in June 1994 when more

funding became available from the Department of Health. All six research assistants were qualified nurses.

It was my responsibility to ensure that the research assistants received adequate training prior to the main data collection period, and further training as and when required. This was achieved through a training programme developed and administered prior to the main data collection period, and additional training given as necessary. A copy of the training programme can be found in Appendix 1. In addition, a seminar course was developed for the research assistants (see Appendix 1). Seminars were held on alternate weeks throughout their period of employment and covered topics such as the economics of HAI, the epidemiology of HAI, study design, basic statistical methods and health policy. Lecturers included myself, other members of the project team and steering committee and external speakers.

1.9.9 Managing the main data collection and entry period

As project leader I was responsible for managing the data collection and data entry process. A variety of techniques were adopted to assist in this process. As discussed above protocols setting out the data collection and entry processes were developed and agreed by the steering committee. The research assistants received training in all aspects of the study. A document outlining the standards to be applied during the data collection period was drafted and approved by the steering committee (see Appendix 2). Each research assistant received a copy of this document which they were subsequently asked to read, discuss and sign. At the outset the research assistants received close supervision. As the project progressed input by myself was reduced. However, the research assistants were free to contact me at any time should they have a query, and I ensured that I met with the research assistants at least once a week at a team meeting.

1.9.10 Appointing a secretary

At the outset the funding available did not allow for the appointment of secretarial support to assist me as project leader, and the other members of the project team. As such, with the exception of some help with a couple of mail merges, all secretarial and administrative work was undertaken by myself. It was clear that some support was needed, and a document outlining the need for additional funds to cover the cost of secretarial support was submitted to the Department of Health. The Department agreed to make available additional funding for administrative support and a secretary was appointed in April 1994. Further support was subsequently employed on an ad hoc basis.

1.9.11 Liaising closely with the research economist and assisting in the development of unit costs for resources used

The project team included a research economist who was primarily responsible for costing resources used by infected and uninfected patients. As project leader, I was a member of the interview panel for the appointment of the research economist. I subsequently worked closely with the economist on all aspects of his work, and assisted in the development and implementation of methods used to cost various resources. For example, I worked closely with the economist to develop unit costs for drugs administered, and procedures performed and I was solely responsible for developing costs for nursing care administered to patients based on the amount of care patients received during the course of their hospital stay.

1.9.12 Liaising closely with the project statisticians

Whilst data analysis was primarily the responsibility of two statisticians, I worked closely with both throughout the study. My role involved assisting in the development of an appropriate strategy for data cleaning, actively engaging in the data cleaning process, and assisting in the development and implementation of an appropriate approach to the analysis of data. As the analysis was undertaken I reviewed and commented on all results, made

suggestions as to how the analysis could be modified, and contributed to the in-depth discussion of the results that followed.

1.9.13 Ensuring that the work is completed within an appropriate time frame

At an early stage it was apparent that, given the scope of the project, it would not be feasible to complete the study within the two years funding available. As such I was responsible for drafting a report requesting an extension to the time frame and additional funding from the Department of Health. The report was well received and an extended time frame together with additional funding was successfully obtained from the Department of Health.

1.9.14 Writing the final report and submitting it to the Department of Health

The final report consisted of four documents: parts I and II, separate appendices, and two stand alone executive summaries that varied in length.[2] Part I included background information, details of the methods used, the results of the study, a discussion of the results, conclusions drawn and recommendations made. Part II included detailed information about the methods used to derive unit costs for resources used. As project leader I was responsible for drafting Part I and the two executive summaries. The research economist primarily drafted part II and the appendices were the responsibility of both the research economist and myself. A copy of the executive summary can be found at the back of this thesis.

Over the course of the project chapters were drafted and circulated to the project Steering Committee for comment and subsequent approval. Drafts were also submitted to the Advisory Committee for comment, and later the Department of Health. A final draft which had been approved by the project Steering Committee was submitted to the Department of Health in August 1997, and distributed for internal and external review. A full set of reviewers comments was received in November 1997. Informal discussion followed and

a formal response submitted to the Department in February 1998 following which there was a further period of discussion and debate. Further editing work and additional analysis was then undertaken. Amendments to the original text, together with the results of the additional analysis requested were submitted to the Department of Health in September 1998 and the report was released for publication in September 1999 and subsequently published in January 2000.

1.9.15 Preparation of the report for publication

The decision was taken that the full report should be published and made available to a wide audience. As such it was agreed that the input of an editor and publication team should be sought. I was subsequently responsible for working with an editor and the Public Health Laboratory production team to produce an edited version of the report.

1.9.16 Liaising with the Department of Health

Throughout the duration of the study I was responsible for liaising with the Department of Health and keeping them informed of any new developments and overall progress. This was done through telephone discussions, letters, reports and presentations made at the advisory committee meetings held regularly over the course of the project.

1.9.17 Liaising with the National Audit Office in relation to their work on HAI

Whilst the cost study was in progress the National Audit Office embarked on a study of HAI. As part of their initial work they approached myself, Jenny Roberts and Nick Graves to discuss the aims and objectives of the cost study. In several subsequent meetings we discussed the questionnaire they were planning to use, advised on a number of issues, updated the NAO about the progress with our study and endeavoured to ensure that any information relating to the cost study was presented appropriately in the NAO report – 'The management of HAI in acute NHS Trusts in England.'[3]

1.9.18 Dissemination of the findings

The final report was launched on February 17th 2000. I was actively involved in this process, working closely with the press officers from the three institutions involved in the research and the Department of Health. I assisted in drafting the press releases and the organisation of the press briefing. As mentioned above the report received considerable media attention, including wide coverage in all the major newspapers. Following the launch I gave a number of interviews for both national and local television and radio stations. The report was subsequently sent to all consultant microbiologists, infection control teams and public health physicians. I was responsible for drafting the covering letter and overseeing this process.

The main results were also reported in a paper published in the Journal of Hospital Infection.[8] I was responsible for drafting this paper, circulating it to the authors for comment and subsequently revising it as necessary and submitting it to the relevant journals.

During the course of the study and since the report's publication I have made a number of presentations to conferences and seminars. Appendix 3 provides details of presentations made over the course of the study.

1.10 My role in this thesis

The preceding section has outlined the key activities undertaken by myself as project leader for the socio-economic burden of HAI study. All the activities listed are directly relevant to this thesis. Additional activities undertaken for the purposes of this thesis include, a more detailed literature review, further cleaning of the data set, further data analysis and the development of an economic model to asses the costs and benefits of investment in prevention. These activities were all undertaken by myself.

1.11 Aims and objectives of this thesis

1.11.1 Aim

To assess the incidence of, and independent risk factors for HAIs occurring in surgical patients admitted to a district general hospital and the impact these infections have on the secondary health care sector, and to examine how the information obtained may be used to assess the potential benefits of investment in the prevention and control of HAIs.

1.11.2 Objectives

The specific objectives were to:

1. Review the literature on the epidemiology of HAI, risk factors for HAI, and the economic evaluation of HAI.

2. Determine the incidence of HAIs occurring in adult, non-day case patients admitted to selected surgical specialties of a district general hospital.

3. Explore how the incidence of HAI varies with selected patient characteristics and identify possible risk factors.

4. Determine the impact HAIs occurring in this patient group have on secondary health care sector resource use and costs.

5. Examine how information on the economic burden of HAIs may be used to assess the potential benefits of investment in the prevention and control of HAIs.

1.12 The structure of the thesis

The thesis begins with a review of the literature. The literature on the epidemiology of HAI is reviewed in Chapter 2. The chapter covers four broad areas: the frequency and distribution of HAI; the mortality risk associated with acquiring an infection in hospital and the number of patients estimated to die from HAIs per year; the aetiology of HAI and specific risk factors for infection, and the problem of antibiotic resistance.

The literature on the economic evaluation of HAI is reviewed and discussed in Chapter 3. The chapter includes a discussion of the methodological issues associated with the economic evaluation of HAI, followed by a review of studies that have estimated the burden of HAI and those studies that have assessed the benefits of prevention.

An overview of the study that examined the socio-economic burden of HAI on which this thesis is based is subsequently presented in Chapter 4, and the methods which are specifically related to this thesis are presented in Chapter 5.

The results of this work are presented in Chapters 6, 7, 8 and 9. Chapter 6 provides an overview of the sample characteristics. Chapter 7 presents the results of the analysis that examined the incidence of HAI and specific risk factors for infection. Chapter 8 presents the results of the economic analysis which examined the impact of HAI on hospital costs and Chapter 9 the results of the analysis that assessed the impact of HAI on length of hospital stay.

How the results of this work might be used to inform clinical practice, is then explored in Chapter 10. Estimates of the gross benefits of prevention at the level of the study hospital and at the national level are presented, together with a framework for assessing the potential net benefits of investment in infection prevention and control activities. A worked example of a simple model of the costs and potential benefits of investment in infection prevention and control activities is presented.

Finally, the results of this study, methodological considerations and the implications for infection prevention and control policy and clinical practice are discussed in Chapter 11 and conclusions drawn.

CHAPTER 2
THE EPIDEMIOLOGY OF HOSPITAL ACQUIRED INFECTION

2.1 Introduction

In this chapter the literature relating to the epidemiology of hospital-acquired infection (HAI) is reviewed. An overview of the epidemiology of HAI in terms of its frequency and distribution, the mortality risk associated with acquiring an infection, and the number of patients estimated to die from these infections every year is provided. The aetiology of HAI including a discussion of specific risk factors for HAI and the problem of antibiotic resistance are also examined. The focus of this chapter will be the problem of HAIs occurring in surgical patients. However, in order to put the problem in context, information relating to the overall problem of HAI will also be presented where appropriate.

The literature reviewed was identified through a series of consecutive searches, carried out during the period 1993 – March 2003, using the computerised bibliographic databases Medline, and PubMed. These two bibliographic databases were selected as they cover the major journals of relevance to this thesis. These searches were supplemented by reference follow up, hand searching of selected journals, and consultation with experts in the field. The search was limited to papers published in the English language during the period 1975 – March 2003, and further limited to studies conducted in developed European countries, the United States of America, Canada and Australia. This time period was selected, as in the mid 1970s the US study of the Efficacy of Nosocomial Infection Control (SENIC), was published representing a time of new understanding and interest in HAIs. As such it was considered appropriate to review literature published from the mid-1970s. The search strategy involved the use of selected key words (thesaurus terms) and combining these with a number of "free text" words. The key words used were: *hospital acquired infection; nosocomial infections; healthcare associated infections; and hospital associated infections.* These were combined with the

following "free text" words: *prevalence; incidence; risk factors; risk indices; antibiotic resistance; antimicrobial resistance; mortality; morbidity* and *deaths.* The abstract of each paper was subsequently read and a decision made as to whether the paper was relevant to this review. Those papers that were concerned with HAIs occurring in adult non-day case patients cared for in specialties common to most hospitals (medicine, surgery, urology, care of the elderly, orthopaedics, gynaecology and obstetrics) were considered to be relevant, as were papers that included both day case and in-patients and papers that included both patients admitted to the specialties listed above as well as those admitted elsewhere. Papers that were limited to day case patients, children, or patients admitted to specialties not included in this study, were excluded from the review.

References cited in papers which had not been identified through the computerised search were subsequently followed up. Hand searches of the following journals were also carried out: Journal of Hospital Infection; Infection Control; American Journal of Infection Control, Epidemiology and Infection Control; Current Issues in Infection Control; and the British Medical Journal. Experts in the field including microbiologists and infection control specialists from the Central Public Health Laboratory Service, at Colindale in North London, and selected NHS Trusts were also consulted to identify grey literature such as project reports and policy documents of relevance to this review.

Some papers identified as part of the review of studies that assessed the economic burden of HAI are also included in this section, since they not only reported data on the cost of infection but also the incidence of HAIs and the number of deaths occurring in infected patients. The results of the socio-economic burden of HAI study, on which this thesis is based, are reported separately in Chapter 4.

2.2 The frequency and distribution of HAI

Data on the frequency and distribution of HAI are available from a variety of sources. A review of the literature indicates that a number of studies have assessed the frequency of HAI either in terms of its prevalence or incidence (see sections 2.3 and 2.4). Many hospitals also routinely collect data on the frequency of selected HAIs, and many participate in national surveillance schemes, the results of which, in some cases, have been published. A recent National Audit Office survey of infection control indicated that in 1998 ~94% of infection control teams surveyed carried out some form of surveillance.[3] Epidemiological, clinical audit and hospital surveillance studies provide useful insights into the extent of the problem of HAI in terms of the frequency of the problem and, in many cases, also provide data on how infection rates vary with specialty, age and other patient characteristics. However, valid comparisons of the results of studies conducted in different settings and over time are difficult. The methods used to determine the incidence or prevalence of HAI employed in the different studies vary in important respects, which in turn impact on the results obtained. For example, studies vary in terms of the case definitions and case ascertainment methods used, the formula used to calculate rates, the types of infections included and the case mix studied. These differences are discussed in detail in sections 2.3 and 2.4, in the context of studies that have assessed the prevalence of HAI (section 2.3) and the incidence of HAI (section 2.4).

2.3 Prevalence of HAI

Prevalence figures are a measure of the proportion of individuals in a population with a specific disease at a single point in time (point prevalence rate) or over a period of time (period prevalence rate) (figure 2.1). Point prevalence figures are more common and have generally been used in studies of the prevalence of HAI. They are usually expressed as a percentage.

Figure 2.1 Prevalence rate formulae

1. Point PR = $\frac{\text{no. persons with a disease at particular point in time}}{\text{total population}}$

2. Period PR = $\frac{\text{total no. persons with disease at some time during the specified period}}{\text{total population at mid-point of interval}}$

PR = prevalence rate

Multicentre prevalence studies have been conducted in a number of countries. Table 2.1 provides an overview of prevalence studies that have been conducted in developed European countries, the US and Australia since 1975. These studies provide important information on both the overall problem of HAIs and the prevalence of infection among specific patient groups.

Table 2.1: Prevalence of HAIs and infected patients as found in studies conducted in Europe, the US, Canada and Australia since 1975

Country	Study author and year of publication	Year of study	No. Hospitals	No. patients	Types patients	Definitions used	Prevalence of infections (%)	Prevalence of infected patients (%)
Sweden	Bernander *et al* (1978)[16]	1975	5	4,246	All patients	Based on CDC 1972 definitions[23]	17.0	-
Denmark	Jepsen *et al* (1980)[17]	1978	25	1,363	All patients	Based on CDC 1972 definitions[23]	-	10.4
Denmark	Jepsen *et al* (1980)[17]	1979	25	1,557	All patients	Based on CDC 1972 definitions[23]	-	12.1
England & Wales	Meers *et al* (1981)[6]	1980	43	18,163	All patients	Study definitions	9.2	-
Norway	Hovig *et al* (1981)[18]	1980	15	7,833	Al patients	Based on CDC 1972 definitions[23]	9.0	-
Italy	Moro *et al* (1986)[24]	1983	130	34,577	All patients	CDC 1972[23]	-	6.8
Belgium	Mertens *et al* (1987)[25]	1984	106	8,723	Surgical or ICU*	Based on CDC 1972 definitions[23]	10.3	9.3
Czechoslovakia	Sramova *et al* (1988)[22]	1984	23	12,260	All patients	World Health Organisation 1981 [26]	6.1	-
Australia	McLaws *et al* (1988)[27]	1984	269	28,643	All patients	Based on CDC 1972 definitions[23]	8.1	-
Spain	EPINE Working Group (1992)[19]	1990	123	38,389	All patients	CDC1988 [28]	9.9	8.5
Spain	Vaque *et al* (1999)[21]	1990	123	38,489	All patients	CDC 1988 [28] + CDC modified SSI (1992) with the exception of asymptomatic bacteruria which was not included in the UTI category	9.9	8.5
Spain	Vaque *et al* (1999)[21]	1991	135	42,185	All patients	CDC 1988 [28] + CDC modified SSI (1992) with the exception of asymptomatic bacteruria which was not included in the UTI category	8.9	7.8
Norway	Avitsland *et al* (1992)	1991	76	14,977	All patients	CDC 1976	6.3	-
France	Sartor *et al* (1995)[25]	1992 (May)	8	1,220	All patients	CDC 1988 [28]	-	8.6**
France	Sartor *et al* (1995)[25]	1992 (Nov)	8	1,389	All patients	Conseil superieur d'Hygiene Publique de France (similar to CDC definitions)	-	7.1**
Spain	Vaque *et al* (1999)[21]	1992	163	44,343	All patients	CDC 1988 + CDC modified SSI (1992) with the exception of asymptomatic bacteruria which was not included in the UTI category	8.5	7.3
UK and Republic of Ireland	Emmerson *et al* (1996)[7]	1993/4	157	37,111	All patients	Study	-	9.0
Spain	Vaque *et al* (1999)[21]	1993	171	46,983	All patients	CDC 1988 + CDC modified SSI (1992) with the exception of asymptomatic bacteruria which was not included in the UTI category	8.4	7.1

SSI – surgical site infection, UTI – urinary tract infection
*Surgical site, blood and urinary tract infections only
** Not clear if prevalence figure relates to prevalence of infections or patients - the latter has been assumed

Table 2.1 continued: Prevalence of HAIs and infected patients as found in studies conducted in Europe, the US, Canada and Australia since 1975

Country	Study author and year of publication	Year of study	No. Hospitals	No. patients	Types patients	Definitions used	Prevalence of infections (%)	Prevalence of infected patients (%)
Crete	Gikas *et al* (1999)[31]	1994	8	1,305	All patients	C CDC 1988 [28] + CDC modified SSI (1992) [29] with the exception of asymptomatic bacteruria which was not included in the UTI category	6.8	-
Spain	Vaque *et al* (1999)[21]	1994	186	49,689	All patients	CDC 1988 [28] + CDC modified SSI (1992) [29] with the exception of asymptomatic bacteruria which was not included in the UTI category	8.3	7.3
Germany	Gastmeier *et al* (1998)[32]	1994	72	14,996	All patients	CDC 1988 [28]	3.6	3.5
Crete	Gikas *et al* (1999)[31]	1995	8	1,386	All patients	CDC 1988 [28] + CDC modified SSI (1992) [29] with the exception of asymptomatic bacteruria which was not included in the UTI category	5.5	-
Spain	Vaque *et al* (1999)[21]	1995	201	51,339	All patients	CDC 1988 [28] + CDC modified SSI (1992) [29] with the exception of asymptomatic bacteruria which was not included in the UTI category	8.0	6.9
Switzerland	Pittet *et al* (1999)	1996	4	1,349	Medical, surgical & ICU	CDC 1988 [28] with the exception of bacteriuria which was not categorised as an HAI	13.0	11.6
Crete	Gikas *et al* (1999)[31]	1996	8	1,279	All patients	CDC 1988 [28] + CDC modified SSI infection (1992) [29] with the exception of asymptomatic bacteruria which was not included in the UTI category	5.9	-
Spain	Vaque *et al* (1999)[21]	1996	206	51,961	All patients	CDC 1988 [28] + CDC modified SSI infection (1992) [29] with the exception of asymptomatic bacteruria which was not included in the UTI category	8.4	7.2
France	Astagneau *et al* (1999)[34]	1996	23	6,389	All patients	Based on CDC 1988 [28] + CDC modified SSI (1992) [29]	-	9.3
France	The French Prevalence Survey Study Group (2000)[35]	1996	830	236,334	All patients	Study	7.6	6.7
Norway	Scheel *et al* (1999)[36]	1997	71	12,755	All patients	Based on CDC 1988 [28]	6.1	-
Spain	Vaque *et al* (1999)[21]	1997	214	51,674	All patients	CDC 1988 [28] + CDC modified SSI (1992) [29] with the exception of asymptomatic bacteruria which was not included in the UTI category	8.1	6.9
Italy	Pavia *et al* (2000)[37]	1999	6	888	All – except psychiatric	CDC 1988 [28] + CDC modified SSI(1992) [29]	1.7	-
Greece	Gikas *et al* (2002)[38]	1999	14	3,925	All patients	Based on CDC 1988 [28] + CDC modified SSI (1992) [29]	9.3	8.6

SSI – surgical site infection, UTI – urinary tract infection

*Surgical site, blood and urinary tract infections only

** Not clear if prevalence figure relates to prevalence of infections or patients - the latter has been assumed

2.3.1 *The overall prevalence of HAI*

Prevalence studies conducted during the late 1970s estimated the prevalence of HAIs to be between 10-17%. In 1975 the prevalence of HAIs occurring in 34,246 patients admitted to five Swedish hospitals was found to be 17%.[16] In 1978 10.4% of 1363 patients admitted to 25 Danish hospitals had one or more HAI and in 1979 12.1% of 1,557 admitted to the same hospitals had one or more HAIs at the time of survey.[17]

Prevalence surveys conducted between 1980 and the mid 1990s generally found the prevalence of HAI to be slightly lower at around 9%.[6 7 18-21] The most recent study conducted in the UK and Republic of Ireland found 9.0% of patients surveyed in 1993 had one or more HAIs at the time of survey.[7] A few studies conducted during this time period found a lower prevalence. In 1984 Sramova *et al* (1988)[22] found the prevalence of HAIs in 12,260 patients admitted to 23 hospitals in Czechoslovakia in 1984 to be 6.1%, and in 1992 a study by Sartor *et al* found that 7.1% of 1389 patients admitted to eight hospitals in France had one or more HAIs, somewhat lower than an earlier estimate for the same year of 8.6%.[20]

The results of prevalence studies conducted since 1995 vary, ranging from a low prevalence of infection rate of just 1.7% observed in a study by Pavia *et al* (2000)[37] involving 888 patients admitted to six hospitals in Italy (Cantazano) to 13% observed by Pittet *et al* (1999) in a Swiss period prevalence study conducted in 1996.[33]

Other studies conducted during this time period found the prevalence of infections to be between 5.9% and 9.3%.[21 31 35 36 38 39] In 1995 a Greek study observed a rate of 5.5% increasing to 5.9% in 1996.[31] In 1996 a French prevalence survey involving 236,334 patients found the prevalence of infection to be 7.6%: 6.7% of patients studied had one or more infections,[35] and a Spanish survey found the prevalence of infections to be 8.4%: 7.2% of the 51,961 patients studied had one or more HAIs.[21] In 1997 a Norwegian prevalence survey found the prevalence of infection to 6.1%.[36] and in 1999 a

prevalence study conducted in Greece found the prevalence of HAI to be 9.3%.[38]

The higher prevalence rate observed in the study by Pittet *et al* (1999)[33] can in part be explained by a number of factors: (I) the study was a period prevalence study, not a point prevalence study; (2) it was conducted in four teaching hospitals where you would expect higher rates than in other types of hospitals; (3) the study was conducted shortly after a national holiday weekend resulting in a low occupancy rate in the hospitals surveyed and a greater likelihood that the population studied were a relatively high risk population compared to the 'normal' hospital population.

If the above results are taken at face value they would appear to suggest that the prevalence of HAI has decreased overtime. However, as indicated in section 2.2 valid comparisons between studies and overtime are difficult. The methods employed to detect HAIs vary, the case definitions used differ, some studies have limited the types of infections included and the types of patients surveyed varies with study. These and other factors will inevitably impact on the prevalence rates observed and are discussed below.

2.3.1.1 Case definitions

The majority of studies have used the Centre for Disease Control (CDC) definitions of HAI or a modified version. Depending on the timing of the study either the 1972 CDC[23] or the 1988 CDC criteria[28] with or without the 1992 modified CDC definition of surgical site infections have been used.[29] Some studies whilst using these definitions have elected to exclude bacteriuria as a diagnosis for a hospital acquired UTI.[21 30 31 33] Others have used a variant of the CDC definitions, adapting them to suit the patient population being studied. For example, a Norwegian study made some slight modifications to the 1998 CDC criteria. Details of the changes made were not presented in the paper.[36] Other studies have used the WHO definitions[40] and a few, such as the UK prevalence study of 1980 and 1996, have developed their own working definitions of

infections.[6 7] However, the first UK prevalence study definitions were based on the CDC criteria and the second UK prevalence study definitions were based on the 1980 working definitions and CDC criteria. The two prevalence studies conducted in France in May and November 1992 used two different sets of definitions. The survey conducted in May used the 1988 CDC criteria, and the survey conducted in November used the definitions of the Conseil Superieur D'Hygiene Publique de France for the diagnosis of infections of the urinary tract, chest (pneumonia), surgical wounds and bloodstream infections, which are similar to the CDC definitions.[20]

Whilst the commonly used definitions are very similar they do differ in a number of important respects that may have an impact on the prevalence rate observed. For example, the criteria for urinary tract infections may vary with respect to whether microbiology evidence is required. Consequently, it is possible that in hospitals where access to microbiology services is limited, or where the culture is such that few specimens are taken, the infection rate will be underestimated. Gastmeier *et al* (1998)[32] found infections rates were significantly higher in hospitals with an on-site laboratory service, than in those who did not have such facilities. However, it is not clear whether the apparent lower infection rate observed in hospitals without on-site access to microbiology facilities reflected an underestimate of the 'true ' rate or simply reflected a different case-mix, which was at relatively low risk of infection, at hospitals where access to on-site facilities were not deemed necessary.

2.3 1.2 Identification methods

The prevalence studies listed in Table 2.1 also vary in the methods used to detect HAIs. The approach generally adopted involved the following. All relevant data sources including treatment charts, case notes and microbiology records were consulted to identify signs and symptoms of infection. If the evidence obtained met the criteria detailed in the definitions used, an infection was said to be present. The majority of studies involved hospital personnel in this process. However, a few utilised external assessors.[41] The degree of

training these staff received varies amongst the studies ranging from just a brief training session,[28] to a relatively substantial training programme.[33] [41] The validity of the results obtained depend on the ability of the staff to comply with the protocol adopted, and assuming compliance, the sensitivity and specificity of the selected approach. There is some evidence that greater accuracy in diagnosing HAI is achieved when better qualified staff are involved and when there is a more substantial training programme.[42]

Inevitably in some cases there will be a degree of uncertainty as to whether an HAI is present. To overcome this, some studies instructed the assessor to indicate the degree of certainty associated with each diagnosis. For example, in the UK prevalence study, researchers were instructed to classify infections as 'certain', 'probable' or 'possible'. In contrast a German study only recorded 'certain' infections.[42] This contributed to the considerably lower overall rate of 3.5% observed in the German prevalence study. When Gastmeier *et al* (1998)[42] reworked the UK estimates only including 'certain' infections the prevalence fell from 9.0% to 4.2%. Whilst this is still higher than the German estimate, it is a considerably closer estimate. Further analysis indicated that if the German estimates were limited to infections occurring in hospitals with a minimum of 600 beds, in line with the types of hospitals included in the UK study, the estimated prevalence increased from 3.5% to 4.4% in line with the UK modified estimate (i.e. limited to 'certain' and excluding 'probable' or 'possible' infections) of 4.2%.[42]

2.3.1.3 Sites of infections included

The majority of prevalence studies aimed to include all types of HAIs. However, a few limited the infections included to the commoner infections. For example a Norwegian prevalence study limited the infections included to the four most frequent infections: urinary tract, surgical wound, lower respiratory tract and bloodstream infections.[36] Limiting the types of HAIs included will inevitably have an impact on the overall prevalence rate, with the result being an underestimate of the overall scale of the problem. Studies also vary depending

upon whether they include all HAIs present on the day of survey[35] or limit inclusion to those acquired during the current admission and exclude those acquired during a previous admission.

2.3.1.4 Rates reported

As indicated in Table 2.1 some studies present prevalence rates based on the number of infections per 100 patients discharged,[6 16 18 19 21 22 30 31 33 35-40] others the number of infected patients per 100 patients surveyed[7 17 19-21 24 25 32 34 35 38 40] with some presenting both data on the prevalence of HAI (all infections) and the prevalence of infected patients who may have more than one infection.[19 21 35 40 38] Studies vary with respect to the criteria used to categorise patients with more than one infection into a specific infection group based on the type of infections identified. Whilst Jepsen *et al* (1980) classified patients according to the primary infection as identified by the investigator,[17] other papers did not provide details about how infections at more than one site were managed.

2.3.1.5 Case mix included

The risk of acquiring an HAI varies considerably with patient population depending on both the intrinsic and extrinsic risk profile (see section 2.8). This risk profile will inevitably vary with case mix surveyed, and this in turn will impact on the overall rates observed. The prevalence of HAI in patients at high risk of a HAI is likely to be considerably higher than in low risk patients. This is clearly illustrated in the sub-group analysis of many of the prevalence studies. For example, the prevalence of HAI in patients admitted to 157 hospitals in the UK and the Republic of Ireland ranged from a low of 0% for dental patients, to a high of 34.2% in patients within the intensive care unit.[7] Other multi-centre studies have also found the prevalence of HAI to vary considerably with specialty group. Consistently these studies have found the prevalence of HAI to be highest in intensive care patients[19 20 22 31 32 34 37 40] and in most cases higher in surgical than medical patients.[17 19 22 31 32 34 37 40] Furthermore, within selected specialties the prevalence will vary depending on the risk profile of the patients studied. For example, the very low prevalence rate observed in the recent

Italian survey by Pavia *et al* (2000),[37] may in part be due to there being a higher proportion of low risk patients in this study compared to other studies. As the authors acknowledge, an earlier study had shown that many patients with complicated conditions migrate to Northern regions or other European countries for treatment.[43] It is likely that the risk of HAI and consequently the infection rate is higher in these migrating patients.

Prevalence studies vary with respect to the patient groups included. Some studies, for example have attempted to survey all patients [6 7 16-18 20-22 24, 27 30 31 34-36 40] whereas others limited their survey to patients admitted to selected specialties.[25 42] A number of studies have focussed on the prevalence of HAI amongst patients treated on intensive care unit[44] and a Belgium study was limited to patients treated in surgical and intensive care units.[25] Where all specialties are included, given that the prevalence of HAI varies considerably with specialty inevitably the proportion of patients within the various specialties will impact on the overall rate observed, again making cross survey comparisons difficult.

Prevalence studies also vary with respect to the types of hospital included. Some studies include all types of hospitals, whereas others are limited to the larger hospitals. For example, the first UK prevalence study was limited to patients treated in hospitals with a minimum of 500 acute beds.[6] Limiting the survey to larger hospitals may result in a higher national prevalence rate than if all hospitals were included as larger hospitals tend to treat populations at higher risk. Participating hospitals may be selected on a representative basis or in other cases hospitals may be asked to volunteer to participate in the study.[7] The latter may introduce selection bias. The prevalence rate also appears to vary with type of hospital, the prevalence being higher in teaching hospitals than non-teaching hospitals. Jepsen *et al* (1980)[17] in a Danish prevalence study observed a prevalence rate of 13.2% in general surgical patients treated in post-graduate teaching hospitals compared to an 4.5% in general surgical patients treated in non-post-graduate teaching hospitals.

The prevalence rate has also been found to vary with care setting (acute, sub-acute or chronic) in part reflecting the differing risk profiles of the patients within these different care settings. A period prevalence study by Sax *et al* (2001),[45] conducted in a hospital in Geneva in May 1998, found that whilst the overall period prevalence was 11.3% within acute settings it was 8.4%, sub-acute 11.4% and chronic settings 16.4%. The odds of acquiring an infection were greater in sub-acute and chronic care settings when compared to acute settings even after adjustment for case mix factors (odds ratios 2.59 and 2.34 respectively).

2.3.2 Prevalence of specific types of HAI

The prevalence of HAI varies considerably with site of infection. Prevalence studies have generally found that infections of the urinary tract (UTI) are the most common, with surgical wound infections (SWIs) and lower respiratory tract infections (LRTIs) consistently forming the other most prevalent sites.[7 31 32 17 19] UTIs accounted for 23.2% of the infections identified in the UK and Republic of Ireland Prevalence Survey of 1993/4, SWIs 11.7%, and LRTIs 22.9%.[7] An exception is a Swiss prevalence study that found SWIs to be the most frequent type of infection (30%) followed by UTIs (22%), and LRTIs (15%).[33] The authors argue that this in part could reflect the fact that their study excluded bacteriuria as a criterion for hospital acquired UTI. It should also be noted that the study was limited to medical, surgical and intensive care patients, which inevitably is likely to have had an impact on the types and frequency of specific types of infections observed. The Greek prevalence study also found a differing pattern.[38] The study involving 3,925 patients admitted to 14 hospitals conducted in1999 found LRTIs to be the most frequent type of infection: LRTIs accounted for 30% of infections identified; UTIs 22.7%; bloodstream infections (BSIs) 15.8% and SWIs 14.8%. The authors suggest that this might reflect the high number of patients in intensive care units on the day of study (6.7%), whilst also noting that the UK prevalence study conducted in 1990[7] also identified an increase in the prevalence of LRTIs.

The need to take into account differences in methodology and the case mix of the patients studied, may be further illustrated by reference to the two large multicentre studies conducted in the UK in 1980[6] and 1993/4.[7] The prevalence of HAI was found to be similar for the two time periods: 9.2% and 9.0% respectively. It cannot, however, be concluded from these two studies that the prevalence of HAI has remained stable overtime. The definitions of infection differed between the two studies, as did the methods used to detect HAI, and this may have had an impact on the prevalence rates observed. However, perhaps more importantly despite the two studies involving patients from similar specialties, important case mix differences were present in the two groups. For example, whereas in 1980 37.7% of males and 40.8% of females were 65 years or over, in 1993 these figures had risen to 48.8% and 50.7% respectively. The NHS was thus treating a significantly older population than previously had been the case, and consequently a population at greater risk of acquiring an infection in hospital. Thus whilst the results may at first appear to suggest that infection rates have remained stable over time, they may in fact reflect an improvement in quality of care, given the higher risk population. However, countering this is the change in discharge patterns that occurred over the intervening years. In 1993/4, patients were being discharged home at an earlier point in their recovery than was the case in 1980. It might be expected that this would have resulted in either an absolute reduction in the prevalence of HAI, and/or a reduction in the prevalence of HAI amongst in-patients and an increase in the prevalence of HAI in the community.

Given the above it is clear that if valid comparisons are to be made between prevalence studies, allowances must be made for differences in the intrinsic and extrinsic risks profile of the populations involved and for differences in the methods used to assess the prevalence of infection. A paper by Gastmeier *et al* (1998)[42] compares the methods used in different prevalence studies, in terms of the definitions used, how hospitals were selected, training of investigators, the proportion of infections accompanied by a positive laboratory result and the availability of data for diagnosing infection (e.g. are laboratory facilities available

and what is the policy on specimen collection), and the date of study. The paper concludes that due to the many methodological differences comparisons of rates between countries should be avoided. However, even in the absence of such adjustment the results of multi-centre prevalence studies clearly demonstrate that HAIs affect a substantial number of patients.

2.3.3 *The prevalence of HAI in patients admitted to surgical specialties*

As indicated above prevalence studies frequently provide information on the prevalence of HAI in patients admitted to specific specialties. The results of these studies clearly indicate that the prevalence varies with specialty and with study. However, for all the reasons indicated above (sections 2.3.1.1 –2.3.1.5) valid cross study comparisons are difficult. Furthermore, the specialty groupings adopted vary. Whilst a number of studies provide data on the prevalence rate amongst surgical patients, in some cases it would appear that this includes infections occurring in both general surgical patients and patients admitted to sub-surgical specialties such as gynaecology, urology and orthopaedics, whereas in other cases the HAI rates presented are limited to general surgical patients, with rates for the other sub-surgical specialties presented separately. For example, Emmerson *et al* (1996),[7] in a paper that presented the main results of the UK prevalence study of 1993/4, reported prevalence rates for nine different surgical specialties, whereas a Greek prevalence conducted in 1999[31] and an earlier Spanish survey conducted in 1990[21] have sub-divided their sample into just two surgical categories: surgical and obstetric and gynaecology specialties combined. Varying specialty groupings together with the factors mentioned in sections 2.3.1.1 - 2.3.1.5 accounts at least in part for the wide variation in prevalence rates observed. For example, the reported prevalence of HAIs amongst surgical patients ranges from a low of just 1.2% observed in a study by Pavia *et al* (2000)[37] to the relatively high level of 13.9% observed in a study by Jepsen *et al* (1980);[17] the reported HAI prevalence rates for obstetric and gynaecology patients range from no infections observed in a study by Gikas *et al* (1999)[31] to 11.1% in a

study by Pavia *et al* (2000);[37] and the reported prevalence of HAI in urology patients range from a low of 7% in a study by Scheel *et al*[36] to 18.6% observed amongst patients admitted to Danish teaching hospital in 1979.[17]

Some papers present data on infections in surgical patients based on the type of surgery conducted (clean or dirty). For example Sartor *et al* (1980) provide rates for clean surgery and other surgery.[20] Others have focussed on the prevalence of SWI according to the type of wound as defined by the wound classification system: clean, clean/contaminated, contaminated or dirty.[19 31] These studies have all found the prevalence to be highest in patients with dirty wounds. However, there is no overall clear trend for infection rates occurring in the other wound categories. For example, a Spanish[19] prevalence study found that the prevalence of SWI increased with increasing contamination of the wound. However, a Greek prevalence study did not observe this trend and found that prevalence amongst the other groupings differed overtime.[31]

2.3.4 *Frequency of specific types of infections occurring in patients admitted to surgical specialties*

A number of prevalence studies provide data on the frequency of specific infections within selected specialties.[7 17 20 32] The pattern observed varies with the study. The most recent UK prevalence study indicated that amongst general surgical patients LRTIs were the most frequent type of infection: 2.6% acquired a LRTI; 2.4% a SWI; 1.9% a UTI and 0.8% a skin infection. Amongst gynaecology patients a different pattern emerged with UTIs being the most frequent type of infection: 5.1% had a UTI, 2.4% a SWI, 1.0% a LRTI and 0.3% a skin infection. UTIs were also the most frequent type of infection amongst orthopaedic and trauma patients and urology patients. In orthopaedic and trauma patients 3.7% had a UTI, 2.8% a SWI, 2.0% a LRTI and 1.4% a skin infection. In urology and uro-surgical patients 6.1% had a UTI, 1.2% a LRTI, 0.8% a SWI and 0.5% a skin infection.

2.4 Incidence of HAI

Incidence measures quantify the number of new cases of a disease that develop in a population of individuals at risk over a specified period of time. There are two specific types of incidence: cumulative incidence and incidence density or force of morbidity.

Cumulative incidence is the proportion of people who develop a disease over a specified period of time (Figure 2.2):

Figure 2.2: Cumulative incidence formula

$$CI = \frac{\text{number of new cases of a disease during a given period of time}}{\text{total population at risk}}$$

CI = cumulative incidence

Cumulative incidence therefore provides an estimate of the probability, or risk, that an individual will develop a disease during a specified period of time.

Incidence density, also referred to as the 'incidence rate' or the 'force of morbidity', measures the number of new cases of a disease during the period of survey and expresses this figure as a proportion of the time each individual remained at risk (Figure 2.3).

Figure 2.3: Incidence density formula

$$ID = \frac{\text{number of new cases of a disease during a given period of time}}{\text{total period - time at risk}}$$

ID = Incidence density

The incidence density of HAI is therefore a measure of the number of new cases of HAI occurring during the period of survey, expressed as a proportion of the time each patient remained in hospital free from infection during the same time period. That is the number of days from time of admission to either time of discharge in the absence of a HAI, or where an HAI is present, the day of onset of the HAI.

The incidence density can be interpreted as the risk of developing a disease per unit of time exposed, and as such it is a more precise measure of the impact of exposure in a population. In addition, determining the incidence density of HAI, as opposed to cumulative incidence, overcomes some of the confounding effects of length of stay. Hospital length of stay will vary, both within and between hospitals, depending on factors relating to case-mix and discharge policies, and this will inevitably have an impact on the cumulative incidence of HAI. If the mean length of stay is relatively short, the number of discharged patients will be relatively high, and as a result the cumulative incidence may appear low, whereas in situations where the mean length of stay is relatively long the opposite may occur.[46]

2. 4.1 Estimates of the incidence of HAI

Studies of the incidence of HAI have tended to focus on specific infections, or infections occurring in specific patient groups, rather than consider the incidence of all types of HAI occurring in a broad case-mix of patients. However, two studies conducted in England do provide important data on the incidence of HAI occurring in a broad case mix of patients.

In 1992, a study involving 3,326 adult patients admitted to the surgical, medical, gynaecology, and orthopaedic specialties of a district general hospital in England found that 7.2% acquired one or more infections that presented during the in-patient stay.[47]

In 1994, an audit of infection control policies and practices in 19 hospitals in England and Wales included an assessment of the incidence of urinary tract, respiratory tract and bloodstream infections (the three most common types of infection), occurring in adult patients, admitted to the medical, surgical, gynaecology and orthopaedic specialties of the selected hospitals and who had a minimum stay of 3 days. A total of 81,218 patient episodes involving 72,434 patients were observed, of which 80,752 episodes involving 72,013 patients could be allocated to specialty groups. Over the study period a total of 2,148 infections were observed, giving a rate of 3.0 per 100 patients and 2.7 per 100 episodes.[1]

Data from the US provide further insight into the incidence of HAI. In 1975, Haley *et al*,[48] as part of a pilot study for the study of the Efficacy of Nosocomial Infection Control (SENIC), assessed the incidence of HAI occurring in 4,067 patients admitted over an 11 week period to a hospital in Atlanta, USA. Of these 5.1% of patients acquired one or more HAIs that presented during the in-patient period, and there were 6.0 HAIs per 100 admissions. UTIs were the most frequent type of infection accounting for 40% of infections observed, followed by SWIs (33%), and LRTIs (16%). Primary bacteraemias accounted for 2% of infections observed and infections at other sites the remaining 9% of infections observed.

Similar results were obtained from the SENIC study itself. The SENIC study investigated the incidence of HAIs occurring in patients admitted to 338 hospitals, representing the 6,449 acute care, general medical and surgical hospitals in the US, over a prolonged period from 1970 - 1975. The HAIs studied were limited to the four most frequent types of infections: urinary tract, surgical wound, respiratory tract and bloodstream. These four infections were thought to account for 80% of all HAIs.[49] A report based on the analysis of a random sample of 169,526 adult patients admitted to these hospitals over a 12 month period in 1975-1976, supplemented with data on the incidence of infections at sites other than those studied in the SENIC study taken from data

from the 75 hospitals participating in the US National Nosocomial Infections Study, and extrapolated to all adult patients admitted to the 6,449 acute sector hospitals, estimated that there were 5.7 infections (all sites) per 100 admissions and that 4.5% of all admissions acquired one or more HAIs which presented during their in-patient admission.[49] Based on the results of the SENIC pilot studies,[48] and the increasing use of medical technology and no corresponding evidence of increased safety or infection control input, the authors concluded that this estimate was likely to be an underestimate of the incidence of HAI.[49]

As with prevalence studies, comparisons between the findings of these three studies should be made with caution. The definitions of infection and the methods used to identify infections, the case-mix of patients studied and the treatment patterns, including discharge patterns, differed with study. Meaningful comparisons are dependent on these and other factors being controlled for.[46 50]

2.4.2 The relative incidence of specific types of infection

Studies that assessed the incidence of HAI occurring in a broad case mix of patients also provide important data on the incidence of specific types of infection. Consistently these studies find urinary tract, surgical wound and respiratory tract infections to be the most frequent types of infection. The study by Glenister *et al* (1992) found that UTIs were the most frequent type of infection, accounting for 27% of all infections observed; SWIs accounted for 23%, and pneumonia accounted for 15%.[47]

Estimates from the US indicate that in 1976/6 urinary tract, surgical wound and respiratory tract infections accounted for 42%, 24% and 10% of the total number of infections estimated to have occurred in patients admitted to the acute sector hospitals that year. [49]

2.4.3 *The incidence of HAIs occurring in patients admitted to surgical specialties*

Studies that have assessed the incidence of HAIs occurring in patients admitted to surgical specialties include those that have assessed the incidence of all types of infection occurring in a broad case mix of patients (including surgical and medical patients), which have subsequently stratified their results by specialty; and studies that have assessed the incidence of all types of HAIs or selected types of HAIs occurring in selected surgical patient groups.

For example, a study by Glenister *et al* (1992) which assessed the incidence of HAIs occurring in medical and surgical adult patients admitted to a district general hospital (DGH) in England observed an overall incidence rate of 7.2%, increasing to 9.7% in patients admitted to the surgical specialties (general surgery, gynaecology and orthopaedics). The incidence amongst general surgical patients alone was 8.7%, in gynaecology patients 9.3%, and in orthopaedic patients 13.6%.[47]

Studies that have limited their focus to the incidence of HAIs or selected types of HAIs occurring in surgical patients include those that have assessed the incidence of infections in patients who have undergone a particular operative procedure such as a caesarean section,[51,52,53-56] or hysterectomy.[57] Others have assessed the incidence of a specific type of infection occurring in a particular patient group. For example, Costantini[58] assessed the incidence of infections occurring in patients cared for on the intensive care unit. Gravel-Tropper *et al*,(1995)[59] assessed the incidence of SWIs in gynaecology and obstetrics patients. Leigh *et al* (1981)[60] conducted an eight year study of post-operative wound infection in two district general hospitals in England between 1971 and 1978. Erbaydar *et al* (1995) [61] in a study primarily concerned with estimating the impact of SWIs on length of hospital stay, estimated the incidence of SWIs occurring in general surgical patients who underwent an operative procedure within a hospital in Turkey.

The estimates of infections within a selected group of patients vary. For example, Henderson in a review of studies that assessed the incidence of SWIs occurring in patients who had undergone caesarean sections found the rate to range from 0-24%.[53] Factors previously mentioned relating to the methodology employed and the case-mix and treatment regimens, may explain much of the variation observed. More recently, Nice *et al* (1996)[55] in an audit of SWIs following emergency and elective caesarean sections in five West Yorkshire Hospitals in the UK, found that of the 628 women who had a caesarean section, 7.2% acquired a SWI. The SWI rates varied between then hospitals ranging from 2.5-17.2%. Analysis of surveillance data collected between January 1997 and December 1998 in eight maternity hospitals in France, found the incidence of all types of infection occurring in patients who had a caesarean section to be 7.4% and just 1.2% for vaginal deliveries.[56]

2.4.4 The incidence of specific types of infection in patients admitted to surgical specialties

2.4.4.1 The incidence of SWIs in patients admitted to surgical specialties

Studies that have assessed the incidence of SWIs occurring in surgical patients have found the incidence to vary. For example, Cruse and Foord (1980)[62] in a ten year prospective study conducted in Canada between 1967 and 1977 and involving 62,939 wounds observed an incidence rate of 5.7%. In the US the National Nosocomial Infection Surveillance System (NNIS), between 1986 and 1996, observed a lower rate. Of the 593,344 operations observed 2.6% were complicated with a SWI[63] More recently, Abussaud and Meqdem (1986) in a study involving 504 surgical patients observed a slightly higher rate: 3.6% of patients acquired a SWI.[64] A similar rate was observed in a randomised controlled study by Lynch *et al*,[65] designed to assess the cost-effectiveness of chlorhexidine body wash as a means of reducing the risk of infection: 3.2% of 3,482 patients had a SWI as defined by purulent discharge from their wound.[65] However, when the definition of SWI was relaxed such that patients who did not have a purulent discharge, but had an ASEPSIS score of more than 10 were classified as infected, the SWI rate increased to 5.8%.[65] A study by Malone *et*

al (2002) also observed a similar rate: 3.2% of the 5031 non-cardiac surgical patients included in the study acquired a SWI.[66]

A slightly lower SWI rate of 2.8% was observed by Culver *et al*[67] in a study conducted in the US. The estimate was derived from data on 84,691 operations performed at 44 NNIS hospitals in the US between January 1987 and December 1990. A smaller study conducted by Kirkland *et al* (1999)[68] in the US in 1999 observed a lower rate: 1.2% of 22,742 patients who underwent in-patient surgery acquired a SWI, and an earlier study by Rubenstein *et al* (1982)[69] conducted in Israel in 1979 observed a SWI rate of 1.9% in general surgical patients and 1.6% in orthopaedic patients.

An earlier study conducted in 1979 and limited to 1,346 patients who had undergone selected abdominal surgery observed a still lower infection rate of 0.97%[70] and a five year prospective study conducted by Krukowski *et al* (1984) involving 1,504 patients who underwent abdominal surgery at a hospital in the UK observed a rate of 2.8%, with over 50% of infections identified post-discharge.[71] However, a study by Bremmelgaard *et al* (1989)[72] involving 42,228 general surgical and orthopaedic patients found that 6.3% of patients acquired a SWI. Garibaldi *et al* (1991) in a study of 1,852 adult surgical patients admitted to university affiliated US hospitals over a four year period observed a similar rate: 6.5% of patients studied acquired a SWI.[73] A study by Mishriki *et al* (1990),[74] which assessed the incidence of SWIs in 702 adult, non-trauma patients of which 600 were in-patients and 102 day cases, observed a higher incidence rate of 7.3% and Erbaydar *et al* (1995)[61] observed a considerably higher incidence rate: 15.2% of the 1482 general surgical patients studied acquired one or more SWIs

The variation in the estimates obtained can again in part be attributed to methodological differences: differing case definitions and detection methods and varying follow-up times. For example, the relatively high incidence rate observed by Mishriki *et al* (1990)[74] can in part be attributed to the definition of

SWI used which was based on clinical data and the fact that infections presenting post-discharge were included in the estimate with post-discharge follow up extending over a period of six weeks: 55% of infections identified presented after the patient was discharged from hospital. In contrast the relatively low SWI incidence rate reported by Culver *et al* (1991)[67] was limited to the incidence of SWI presenting during the in-patient period and relates to the incidence of SWI as defined by relatively strict criteria.

The impact of case definitions and case detection methods on the rates obtained was highlighted in a short report by Reilly *et al* (2001).[75] Over a 28 month period 1,772 patients admitted to a hospital in the UK were followed for a period of 30 days following clean surgery. The utilisation of a relatively strict definition for SWI that required the presence of pus from the wound resulted in a SWI rate of 5%. A wider definition resulted in a SWI rate of 8%. These estimates relate to SWIs presenting within 30 days of clean surgery. If however the time period of interest was limited to infections presenting during the in-patient period then the 8% rate fell to an artificially low rate of 1%.

A recent systematic review to assess the evidence of validity and reliability of the definitions and detection methods used in prospective studies of SWIs published between 1993-1999, highlighted the wide variation found in these studies with respect to these factors, and how this impacts on the estimates of infection rates derived and importantly limits valid comparisons being made.[76] Forty-one different definitions of SWI were used in the ninety studies included in the review, of which only five were definitions proposed by multi-disciplinary groups.[28 77-80]

Whilst methodological differences clearly have an impact on the overall rates observed, case mix differences perhaps play a greater role. Data on the incidence of SWI and how this varies with wound class clearly demonstrate the impact that case mix differences have on rates. As might be expected studies consistently found the SWI rate to be considerably lower in clean surgery than

in contaminated surgery. Cruse and Foord's (1980) ten year study of wound infections clearly showed this. Whilst Cruse and Foord's[62] study observed an overall SWI rate of 4.7%, rates varied markedly with wound class. The SWI rate in clean surgery was just 1.5%, rising to 7.7% in clean-contaminated surgery, 15.2% in contaminated surgery and 40% in dirty surgery.

More recent studies have continued to observe variation in rates according to wound class. For example, whilst Abussaud and Meqdem (1986)[64] in their study involving 504 surgical patients observed an overall incidence rate of 3.6%, the rate was found to vary from a low of just 1.1% for patients who underwent clean surgery to 18.5% amongst patients who underwent contaminated surgery. Similarly Bremmelgaard *et al* (1989)[72] in their study involving 42,228 general surgical and orthopaedic patients found the SWI rate varied from a relatively low rate of 2.3% in patients who underwent clean surgery to a high rate of 27.1% in patients who had dirty wounds, with an overall rate of 6.3%. However, Malone *et al* (2002)[66] observed a slightly different pattern. In their study of 5,031 non-cardiac surgical patients infection rates were lowest in the dirty wound category: just 1.8% of patients classified as having undergone 'dirty-infected' surgery acquired a SWI. This compared to rates of 2.4% in patients who underwent 'clean' surgery, 4.2% in patients who underwent 'clean-contaminated' surgery and 4.6% in patients who underwent 'contaminated surgery'. The authors attributed this finding to either the relatively low number (57) of dirty cases studied or differences in wound care practices.

This variation in SWI rates according to wound class category inevitably has an impact on the overall SWIs rate observed. The overall rate will clearly depend to some extent on the proportion of patients within each wound class category. The distribution of other intrinsic and extrinsic risk factors will also have an impact on the rates observed. These are discussed in section 2.8.

2.4.4.2 *The incidence of UTIs in surgical patients*

While studies that have assessed the incidence of UTIs in patients admitted to both medical and surgical specialties suggest that between 1 and 3% acquire a UTI;[81] [82] studies limited to surgical patients generally suggest that the incidence amongst surgical patients is considerably higher.[14] Coello *et al* found that 6.3% of adult patients admitted to the surgical, urology, gynaecology and orthopaedic specialties of a DGH in England and who had an operative procedure acquired a UTI.[14] Bueno-Cavanillas *et al* (1991)[83] in a study involving 449 surgical patients admitted to a hospital in Spain in 1986 observed an incidence of 8.7%. A study by Melatomaa *et al* (2000)[57] which assessed the incidence of HAIs occurring inpatients who had either an abdominal hysterectomy 516 (75%); vaginal hysterectomy 105 (15%); or laproscopic hystectomy 66 (10%), at a Finnish University Teaching Hospital during the period October 1993-September 1994, observed a higher UTI incidence rate of 13.5%. An exception is a study by Rubenstein et al (1982),[69] conducted in Israel in 1979: 3.1% of the 967 general surgical patients surveyed and 2.9% of the 968 orthopaedic patients surveyed acquired a UTI.

2. 4.4.3 *The incidence of LRTIs in surgical patients*

Incidence studies have generally found 0.8 – 0.9% of medical and surgical patients acquire a respiratory tract infection with the rates varying with type of patient.[84] [85] A number of studies have focussed specifically on pneumonias occurring in ventilated patients (ventilator- associated pneumonias- VAP). The incidence of VAPs has been found to vary from 10% to 65%.[86-92] [93] [94]

2.4.4 *Evidence of inter-hospital variation*

Evidence from national surveillance schemes indicates that infection rates vary between hospitals which cannot be explained by case mix differences.[95] [96] For example, data from the UK National Nosocomial Infection Surveillance Scheme indicate that the incidence of surgical site infection varied with both the category of procedures and hospital. Similarly the incidence of bacteraemia varied by specialty and within specialty between hospital sites. This inter-hospital

variation remained after controlling for age structure and other case mix differences.[5] Given that the hospitals involved in this national surveillance scheme all used the same data collection methods the results suggest that factors relating to policies and practice may account for the variation observed.

2.4.5 Infections presenting post-discharge

The problem of HAI is not restricted to the hospital stay: a proportion of infections do not present until after the patient has been discharged from hospital. Prevalence studies fail to take into account these infections and incidence studies, until recently, have generally focused on infections presenting during the in-patient phase. As a result these studies inevitably underestimate the scale of the problem of HAI.

Studies examining the incidence of SWIs presenting post-discharge indicate that anything from 20-86% of SWIs present post-discharge.[57 65 71 74 97-105] The variation in the proportion of infections identified post-discharge may be explained, at least in part, by reference to the different methods used to identify infections, differences in the case-mix of the population studied and varied discharge patterns.[104 106]

2.5 National estimates of the number of HAIs occurring per annum

National estimates of the number of HAIs occurring per annum and/or the number of patients who acquire one or more HAIs have been derived. For example, in the US Haley *et al,*[49] based on data from the SENIC study and the NNIS survey, estimated that there are at least 2.1 million HAIs per annum. The authors suggest that whilst this figure is substantial it is likely to be an underestimate of the scale of the problem. They argue that as a result of advances in medical technology, it is now possible to treat patients who in the past were untreatable. Many of these patients are at high risk of acquiring an infection. Whilst medical advances have facilitated treatment there is no substantial evidence of improved infection control. As such it is argued that the

actual figure is likely to be closer to 4 million. Estimates of the number of HAIs occurring in surgical patients alone were not presented

In the UK in 1997 Glynn *et al* [1] estimated that were at least 100,000 HAIs every year. This estimate was derived from estimates of the incidence of chest, urinary tract, and bloodstream infections occurring in adult patients admitted for a minimum of three days to the medical, surgical, orthopaedic and gynaecology specialties of 19 district general hospitals in England and Wales in 1996. Extrapolating the results of their study to the national level the researchers estimated that there were 60,000 HAIs of the urinary tract, respiratory tract or bloodstream per year. When infections occurring in patients admitted to other specialties are taken into account, together with skin and SWIs then this figure was estimated to increase to 100,000 infections per annum. Estimates of the number of HAIs occurring in surgical patients alone were not presented

2.6 Impact of HAI on mortality

HAIs may directly cause death, substantially contribute to the terminal event, or have little or no role in a patient's death.[107] In any individual case it is difficult to tease out the contribution of the infection to the terminal event. The role that HAIs play in hospital deaths inevitably varies with type of infection, and the patients underlying disease and health status.

Studies that present information on mortality rates in infected and uninfected patients show that the mortality rate is significantly higher in infected than uninfected patients.[108-110 89 91 111 112 68 92 113-118] An exception is a study by Freeman *et al* (1979). Eighty-five infected patients admitted to a US hospital in 1973 were matched with suitable controls. Little overall difference in mortality rates between infected and uninfected controls was found. However, as acknowledged by the authors the sample was relatively small and as such insufficient to pick up a small but statistically significant increased risk if present.[111]

The higher mortality rate generally observed amongst infected patients may reflect both the increased mortality risk that HAIs present, and marked differences in the distribution of other mortality risk factors in the two groups (infected and uninfected patients). The case mix of the infected group may, even in the absence of an infection, render the infected patients at greater risk of in-patient death than the uninfected patients, with many of the risk factors for HAI also being risk factors for mortality.[118]

The results of a prospective study of 4,714 patients admitted to three Spanish hospitals in 1994/5 provide evidence that many of the risk factors for infection are simultaneously risk factors for mortality.[118] The study assessed whether the SENIC and NNIS indices of intrinsic infection risk were also good predictors of in-hospital mortality. The results of the crude data analysis indicated that both indices were related to in-patient mortality. However, the results of the regression analysis which controlled for the potential confounding effects of age, sex, American Society of Anaesthesiologists scores (ASA score), cancer, renal failure, diabetes mellitus and a stay on the intensive care unit, found that the SENIC index ceased to demonstrate a significant trend with mortality ($p = 0.025$), while the NNIS index did demonstrates a significant trend ($p=<0.001$).

The higher mortality rates observed in infected patients may therefore to some extent reflect the underlying mortality risk. Consequently, deaths occurring in infected patients may not be directly attributed to the presence of an infection but attributable to other factors. The task therefore is to assess the specific contribution of the infection to death. Studies that have attempted to do this vary in their approach.

2.6.1 Methods used to assess the impact of HAI on mortality

2.6.1.1 Review of case notes

In some studies case notes of deceased patients were reviewed and a judgement made as to whether the infection was the primary cause of death or a substantial contributing factor. Gross *et al* (1980)[119] present guidelines for determining whether the presence of an HAI directly caused the patients death or acted as a contributing factor. However, as Salemi *et al* (1995)[115] point out even in the presence of guidelines categorising patient deaths in this way can be difficult. Salemi *et al* (1995) argue for one category that combines both deaths directly caused by HAI and those in which the presence of an infection was a contributing factor, suggesting this would improve the validity of the mortality data.[115]

2.6.1.2 Autopsy examination

Other studies rely on the results of autopsy examination for information on the number of deaths resulting from a HAI.[110] For example, Daschner *et al* (1978) examined autopsy data from 1000 patient autopsies during the years 1975 – 1976. In their study, autopsy findings, complemented by a review of medical records and the clinical judgement of a pathologist, were used to determine the presence of an infection and subsequently categorise patients into those whose HAI directly led to death and those in which the HAI was a contributing factor to the terminal event. The criterion used for allocating patients into these two groups was not published. HAI was identified as the direct cause of death in 7.4% and a contributing factor in 6.3% of the 1000 autopsies examined, and found to be either the direct cause of death or a contributing factor in 80% of those autopsied patients who had an infection.

2.6.1.3 Review of death certificates

An alternative approach adopted by some studies has been to review death certificates to identify patients for whom HAI has been listed as the cause of death.[115] This approach is thus reliant on the cause of death being accurately recorded on the death certificate. Failure to report deaths from HAI on the

death certificate will in some cases result in the death rate being underestimated. Salemi *et al* (1995)[115] in their study of deaths occurring in patients admitted to a single US hospital who had acquired either a pneumonia, primary BSI or SWI, found the number of deaths attributable to an infection increased when the case notes of patients with pneumonia or BSI whose death certificate did not list infection as a cause of death were examined. Twenty-four per cent of patients who acquired a pneumonia and 25% of patients who acquired a BSI died. An examination of death certificates alone indicated that the infection was either the direct cause or a contributing factor in 15% of deaths occurring in patients with a pneumonia or BSI. Following an examination of case notes of those patients for whom the infection was not listed as the cause of death on the death certificate, the proportion of deaths attributable to the infection increased to 20% in patients who had a pneumonia and 19% in patients who had a BSI.[115] Both of these increases were significant ($p<0.05$).

2.6.1.4 Case control approach

Other studies have adopted a case control approach to adjust for severity of underlying illness.[108 109 113, 68 91 111 120 121] For example, Rose *et al* (1977)[108] compared mortality rates amongst 40 patients with hospital acquired BSIs with that occurring in 40 uninfected matched controls treated at a US hospital between December 1972 and August 1974. The mortality rate in bacteraemic patients was 38% compared to just 10% in controls. During this time period a further 84 patients had a BSI, however medical notes were not available in 19 cases and suitable control patients could not be found in the remaining cases. The mortality rate amongst these unmatched bacteraemic patients and 109 additional bacteraemic patients admitted to the study hospital between January and October 1975 was 34%. The inability of this study to find suitable controls for all infected patients is a common problem associated with this approach,[109] and inevitably may introduce bias into the mortality estimates derived.

2.6.1.5 *Data stratified by underlying risk*

To enable more valid comparisons in death rates both over time, and between institutions, some studies have assessed the death rate in infected patients and then stratified the data by underlying risk. For example, a study by Salemi *et al* (1995), based on infection data from a single US hospital for the years 1987-1992, assessed the number of deaths that were either primarily due to the presence of an infection or in which the infection played a substantial role and subsequently stratified the data by underlying risk based on the patients severity of illness.[115] The severity of illness classification system used consisted of five categories ranging from no risk of death expected during the patients hospital admission to almost certain death expected. For the purpose of their work the five categories were collapsed into an 'at risk of death during hospital admission group' and a 'not at risk of death during admission group'. Of those patients who had acquired a BSI and had been classified as 'not at risk of death' the infection either directly caused or contributed to death in 5% of cases, whereas in patients who had acquired a BSI and had been classified as 'at risk of death', the infection either directly caused or contributed to the patients death in 21% of cases. The association between pneumonia and death in the 'not at risk of death' and 'at risk of death' groups was 13% and 23% respectively. The authors concluded that if valid comparisons are to be made mortality rates should be stratified by risk.

2.6.1.6 *Regression analysis*

Regression analysis is another technique that has been used to control for factors other than the presence of an HAI which might contribute to the patient's death and delineate the role of the HAI.[89 91 92 112 118] For example, a study by Fagon *et al*[92] conducted a stepwise logistic regression analysis which assessed the independent effects of nosocomial pneumonia on mortality risk in intensive care patients. The analysis controlled for a range of factors known to be associated with mortality in intensive care patients. The results indicated that after controlling for a range of other factors, patients who acquired a pneumonia were 2.1 (95% CI: 1.8, 3.6) times more likely to die than uninfected patients.

2.6.2 *Specialty specific mortality rates*

Studies that have examined in-patient deaths and more specifically the contribution of an infection to death have generally found that infections occurring in surgical patients were more likely to cause or contribute to death than infections occurring in patients admitted to non-surgical specialties.[110 119] For example, Gross *et al* (1980) found that whilst more deaths occurred on the medical services only 25% were associated with the infection, whereas on the surgical specialties half of the deaths were associated with infection. A study by Daschner *et al* (1978) also found that most infections causing or contributing to death were acquired on surgical specialties.[110]

2.6.3 *Site-specific mortality rates*

The impact of HAI on mortality risk whilst depending on the patient's underlying condition and the interplay between the infection and the patient's condition, will also vary with type of infection. The results of studies which have assessed site specific death rate have generally found that death rates are higher in patients with bloodstream and lower respiratory tract infections than in patients with a UTI.[119] For example, unpublished data from the NNIS system in the US which was presented by Hughes *et al* at the Twenty-second Interscience Conference on Antimicrobial Agents and Chemotherapy, and reported in an article by Martone *et al.* (1998),[122] indicated that whilst overall 0.9% of patients with an HAI die as a direct result of the infection and in a further 2.7% of cases the HAI is a substantial contributing factor there was considerable variation in attributable risk by site. Pneumonia and BSIs were found to be greater risk factors for mortality than infections at other sites: 4.4% of deaths were directly attributable to bloodstream infections and 8.6% partially attributable; 3.1% were directly attributable to pneumonia and 10.1% partially attributable. This contrasts with 0.8% of deaths attributable to 'other sites' and 2.5% partially attributable to 'other sites'; 0.6% directly attributable to SWIs and 1.9% partially attributable to SWIs; and 0.1% directly attributable to UTIs and 0.7% partially attributable to UTIs.

Interestingly whilst the risk of death is generally found to be relatively low in patients who acquire a UTI, a study by Platt *et al* (1982) indicated that after controlling for a number of other factors including severity of illness, age and duration of catheterisation, the presence of a hospital acquired UTI was associated with a three-fold increase in risk of mortality.[112] While it was acknowledged that the presence of a significant association between infection and mortality is not necessarily indicative of a causal relationship, and that the possibility remains that the UTI was a marker for a factor not included in the logistic regression analysis, the later was not thought to be the case.

The study by Salemi *et al* (1995) referred to above, based on infection data from a single US hospital for the years 1987-1992 assessed the number of deaths that were either primarily due to the presence of an infection or in which the infection played a substantial role.[115] This study found that 19% of patients who had a BSI and 20% of patients with pneumonia subsequently died as a result of infection compared to just 1% of patients with a SWI who died from infection. The authors subsequently compared this to CDC rates of 13%, 13% and 2.5%. There were no significant differences in the rates observed for both BSI and SWI but there were for pneumonia.

Delgado-Rodriguez *et al*(1999)[118] in their study of 4,714 surgical patients admitted to three Spanish hospitals in 1994/5 mentioned above found that after controlling for a range of potential confounders (age, sex, presence or absence of a cancer, renal failure, or diabetes, stay in the ICU and the NNIS index), the presence of an organ/space surgical site infection was significantly related to mortality (Odds ratio 4.9: 95% CI: 1.5 – 15.6) as were BSIs (Odds ratio17.3: 95% CI: 3.5 – 87.0). The acquisition of a single infection at the following sites was not significantly associated with mortality: superficial incisional wound infection; deep incision wound infection, respiratory tract infection, urinary tract infection, infections at sites other than these. In those patients who had more than one infection the combination of a surgical site and respiratory tract

infection or a surgical site and bloodstream infection was significantly associated with mortality, but other combinations were not.

The analysis of data from the French surgical site infection surveillance network (INCISO) for the years 1997-1999 indicated that the crude mortality rate amongst patients with a SSI was considerably higher than in uninfected patients: 5.8% and 1.35 respectively.[123] The attributable mortality rate was thus 4.5%. After adjustment for a range of risk factors including sex, age, NNIS risk index, length of hospital stay prior to surgery, type of surgery (elective or emergency) and the presence or absence of endoscopic surgery, it was estimated that 38% of deaths occurring in infected patients were directly attributable to the infection. Subjective surgeon assessment estimated that 25% were directly attributable to the infection, a rate that was also reported by the US NNIS system.[124]

A case control study by Kirkland *et al* (1999)[68] examined surgical site infections and mortality. Over a four-year period (1991-1995) 272 patients who underwent surgical procedures at a hospital in the US acquired a surgical site infection. Of these 255 (94%) were successfully matched with uninfected controls. Mortality rates were found to be twice as high in infected than uninfected patients: 7.8% of infected patients died compared to just 3.5% of uninfected patients.

A study by Leu *et al* (1989) which focused on hospital acquired pneumonia in 115,921 patients admitted to a US hospital over a five year period from January 1st 1979 to December 31st 1983, observed a mortality rate of 30% amongst the 890 patients who acquired a pneumonia (initial episodes only). The attributable mortality, derived from a case–control analysis of a sub-sample of 74 patients, was estimated to be 33%.[91]

A case control study by Rose *et al*[108] focussed purely on BSIs occurring in patients admitted to a US hospital over a two year period from December 1972 to August 1974. Over this period 124 patients had a BSI. Medical records were

available for review in 105 cases. Adequate control patients were identified for just 40 of these cases. The crude mortality rate in patients with a BSI was 38% compared to 10% in uninfected controls. The authors acknowledged that the failure to find suitable matches for all cases may have introduced bias into the results. As such cases for which no controls could be found were also reviewed together with an additional 125 BSIs occurring in 113 patients admitted between January 1975 and October 1975. The medical records were available for 109 of these additional cases. The mortality rate amongst the 65 unmatched cases and the 109 additional cases was 34%. A study by Sprengler *et al* (1978)[109] observed a similar mortality rate: 30% of patients with bacteraemia died compared to 4% of uninfected matched controls giving an estimated attributable mortality rate of 26%. Estimates of the risk ratio for death indicated that infected patients were 14 times more likely to die than uninfected patients.

A case control study of hospital acquired BSIs occurring in 4,002 critically ill patients treated on the surgical intensive care unit indicated a lower risk ratio. The study observed a crude mortality rate of 50% in infected patients compared to just 15% in matched uninfected patients.[113] The estimated attributable mortality rate was therefore 35% (95% CI: 25%, 45%), a higher rate than that observed in the study by Sprengler *et al*. However, the risk ratio for death was lower: 3.31 (95% CI: 1.78, 6.15).[113]

Other studies which have specifically examined the relationship between bacteraemias and mortality indicate that BSIs resulting from hospital acquired UTIs have a case fatality rate of between 13 and 30%.[125-127] However, the majority of deaths occurred in patients with severe underlying disease.[125]

2.6.4 Specialty and site-specific mortality estimates

Some studies have focussed on infections occurring in selected patient groups and/or specific infections occurring in selected patient groups. For example, a number of studies have assessed the impact of pneumonia on mortality in patients treated on intensive care units. A study by Fagon *et al* (1996) involving

1,978 patients admitted to an ICU, observed a death rate in patients who acquired a pneumonia of 52.4% compared to 22.4% in patients who had not acquired a pneumonia. Multiple stepwise logistic regression analysis was subsequently conducted to assess the independent effect of hospital acquired pneumonia on mortality risk in patients admitted to the ICU.[92] The results of their multivariate analysis that controlled for a range of factors known to be strongly associated with death in ITU patients indicated that pneumonia was an independent risk factor for mortality in these patients (odds ratio: 2.1 (95% CI: 1.6, 2.8). BSIs were also associated with an increase risk of death (OR: 2.5; 95% CI 1.8, 3.6). The acquisition of a UTI was significantly associated with mortality in the univariate analysis but as in other studies was not significantly associated with mortality in the multivariate analysis.[89]

In contrast to this, a study by Craven *et al* (1988) found that whilst pneumonia was associated with death, it was not among the seven variables remaining after multivariate analysis, thus highlighting some doubt about the direct effect of pneumonia on death.[89] The rigorous approach to the diagnosis of pneumonia may in part explain the different findings. Fagon *et al* (1996)[92] adopted strict criteria for the diagnosis of pneumonia. The diagnosis was dependent on microbiological evidence of infection. All patients who developed a new and persistent infiltrate and had purulent tracheal secretions underwent immediate fiberoptic bronchoscopy at which time specimens were taken using a protected specimen brush and bronchalveolar lavage. Diagnosis was then confirmed from the results of the diagnostic tests. This strict approach distinguishes their study from earlier studies which included clinically diagnosed pneumonia and thus probably includes patients with lung processes that mimic pneumonia. The authors offer this distinction as a possible explanation for the differences observed between their results and that of earlier studies that failed to identify pneumonia as a risk factor.[87 89 128] However, it is of course possible that the very process of conducting a fiberoptic bronchoscopy may have increased the patient's mortality risk.

2.6.5 Number of deaths associated with HAIs per annum

Estimates of the number of deaths occurring annually within a given country are also presented in the literature. For example, in the US, Haley combined data from the SENIC study[49] with data from a concurrent assessment of mortality performed in the NNIS system[129] to derive estimates of the number of deaths either directly or partially attributable to infection. The results indicated that in 1982, an estimated 19,027 deaths were attributable to HAI and a further 58,092 deaths partially attributable to HAI.[122] If these estimates are accepted, then in 1982 deaths from HAI alone were the 11th leading cause of death in the US, and deaths that were partly or solely attributable to HAI, were the 4th leading cause of death.[11]

Equivalent data are not available for the UK. However, assuming a similar mortality rate, it has been estimated that 5,000 in-patient deaths per year might be primarily attributable to HAI and a further 15,000 in-patient deaths might be partially attributable to an infection acquired in hospital.[9] These estimates are inevitably crude; however, they represent the best estimates available to date.

2.7 Aetiology of HAI

This section provides an overview of the aetiology of HAI drawing on a range of literature in recognised texts on issues relating to hospital infections and where appropriate relevant papers.[130-132]

HAIs occur when micro-organisms invade a patient and cause disease. The micro-organisms may be from an endogenous source that is from a site within the patient, or from an exogenous source e.g. from another patient or from the environment. If the causative micro-organisms are normally present in the patient (a commensal) an infection may develop as a result of a change in the relationship between the micro-organisms and the patient. If the micro-organisms are transported from an external source to the patient, an infection may develop if the balance between the agent and the patient's defences favours the micro-organisms. The interaction between micro-organisms, the

route of transmission and patient is called the chain of infection. The environment had a significant impact on all elements in this chain.

2.7.1 Micro-organism/Pathogen

A micro-organism that leads to a disease state in an individual is called a pathogen. It can be a bacterium, a protozoan, a virus or a fungus, although the vast majority of HAIs are caused by bacteria.[6 19 20 77] The ability of the organism to cause disease, its pathogenicity, varies considerably amongst the diverse members of the microbial world. For example, *Staphylococcus aureus (S. aureus)* is a major pathogen responsible for between 10 and 20% of HAIs,[6 19 20 77] and has relatively high pathogenicity compared to *Staphylococcus epidermidis (S.epidermidis),* a member of the same bacterial genus (Micrococcaceae). *S. epidermidis* is a normal skin commensal and rarely associated with significant infection in a non-susceptible host. The relatively high pathogenicity of *S. aureus* can be attributed to the presence of specific virulence factors that enhance its potential ability to cause disease.

Virulence refers to the degree of pathogenicity of an organism and may be described by reference to epidemiological factors including morbidity, mortality and communicability, or by clinical factors characterising the severity of the infection observed. Organisms such as *S. aureus, Streptococcus pneumoniae and Mycobacterium tuberculosis* can be regarded as principal pathogens, regularly causing disease in immunocompetent individuals. However, when considering the aetiological agents involved in HAI, a considerable number of non-principal organisms are implicated. *Pseudomonas aeruginosa, Enterococcus faecalis* and indeed *S. epidermidis* are major causes of HAI and yet rarely cause disease in people with intact host defences. Such organisms can be regarded as opportunists. This opportunism is a direct result of hospitalised individuals being more likely to lack an intact innate or acquired immune system, and therefore make up a more susceptible population.

2.7.2 Route of transmission

Micro-organisms can be transmitted to patients by a variety of routes including direct contact (e.g. hands of staff), indirect contact (e.g. via a piece of equipment), by the airborne route in droplet nuclei, by ingestion (e.g. contaminated hospital food) or by inoculation (e.g. via blood transfusion).

2.7.3 Patient

Individuals are protected from microbial invasion by non-specific and specific defence systems. The non-specific defence system includes the skin, mucous membranes, certain bodily secretions and the inflammatory response. The intact skin provides a tough outer layer which few microbes can penetrate. Anti-bacterial substances, present in the sweat and the secretions of the sebaceous glands, add further protection, and microbes normally found on the skin (e.g. *S. epidermidis)* protect against invasion by pathogens through competition for nutrients. The mucus membranes of the respiratory tract produce mucus that traps particles that enter the airway. The cilia then move the mucus upwards to the oropharynx where it is swallowed or expectorated. Lysozyme, present in tears and saliva, is capable of breaking down (lysing) bacterial cell walls especially those of Gram positive bacteria. Finally, the inflammatory response, classically characterised by redness, heat, swelling and pain at the site of invasion represents the initiation of the specific defence system. This system comprises the humoral and cellular arms of the immune system. Both may be acquired naturally through infection or artificially through vaccination.

Within the hospital environment individuals are exposed to greater microbial risk than in the community. On admission to hospital the normal skin flora are often replaced by strains of hospital bacteria that are more resistant to antibiotics and can cause serious infection if they enter the body. Northey *et al* (1974) in a study of intensive care patients found that within two weeks of admission nearly every patient was colonised with infective bacteria and this often involved resistant organisms.[133]

Medical and surgical therapies often require therapeutic interventions that breach the natural defence mechanisms providing a route of entry for invading micro-organisms. For example, surgical procedures and intravenous therapy result in a break in the integrity of the skin, and urethral catheterisation provides a direct route of entry for micro-organisms to enter the urinary tract: micro-organisms may enter during the process of catheterisation, or they may travel retrogressively through, or along, a urinary catheter. Similarly the insertion and presence of an endotracheal tube provides a direct route of access for micro organisms, bypassing the protective action of the mucous membranes and cilia of the lungs, which may also be inhibited by drugs administered.

Whilst the presence of a route of entry increases the risk of infection, it does not necessarily follow that an infection will result. The development of an infection is dependent on the pathogenicity of the invading agent, and the susceptibility of the host, in this case the patient. The very young are particularly susceptible since their immune system is in an immature state. The elderly are similarly at greater risk since their immune system is less efficient. Patients with illnesses that affect the immune system, such as AIDS, leukaemia and other haematological malignancies are particularly vulnerable to infection. These patients who are generally immuno-suppressed and as such susceptible to infection, are made more vulnerable by the toxic effects of the drug therapy they receive. See section 2.8 for a more detailed discussion of risk factors for infection.

2.7.4 Environment

Environmental factors such as temperature, air movement and the presence of chemicals, gases and toxins may have an effect on any of the factors involved in the development of infection. Particular environmental factors may limit, inhibit or prevent the development of an infection. For example, environmental factors such as temperature and humidity may promote or inhibit the growth of micro-organisms in their reservoir. Movement and velocity of the air may affect transmission of micro-organisms from source to susceptible host.

2.8 Risk factors for HAI

As indicated above infections occur as a result of complex interactions between specific factors relating to the patient's condition, the treatment administered and the environment (see section 2.7). The risk of acquiring an infection in hospital therefore varies considerably from one patient to another. Studies that have assessed risk factors for HAI have identified a number of factors that are significantly associated with the presence of HAI. However, these factors are not necessarily causative factors – they may simply be closely related to the actual risk factor and, as such, act as a marker for the risk factor. Furthermore, some risk factors may occur simultaneously with other factors, exerting an additive or even synergistic effect: that is they are interrelated. Thus when examining risk factors for infection the problem is not only to find factors that are significantly associated with HAI, but also to identify which factors are independently associated with the presence of an infection.

The technique adopted to do this has generally been multiple logistic regression analysis. Those factors identified in the univariate analysis as being significantly associated with the presence of an infection are entered into a logistic regression analysis in an attempt to identify independently significant factors. However, the possibility still arises that the factors identified are markers for other factors. Thus the validity of the results obtained are to some extent dependent on the completeness of the original variables introduced – how comprehensive the list of variables included was.

Risk factors for infection can be classified into two broad groups: intrinsic risk factors and extrinsic factors. Intrinsic risk factors are specific factors relating to the patient's condition that place them at risk of acquiring an infection, they reflect the patient's susceptibility to infection. Patients with conditions that affect the immune system, such as leukaemia and HIV, are inevitably at greater risk of acquiring an infection than patients without these conditions. Other intrinsic risk factors include old age, diabetes, and obesity. Extrinsic risk factors relate to factors external to the patient and include factors that increase the risk of micro-

organisms entering the patient. For example, medical interventions that breach the intact protective skin barrier and urethral catheteristaion which provides a direct port of access for invading micro-organisms.[107]

There are many examples in the literature of studies that have examined risk factors for HAIs at any site or specific sites.[62 134 135 136 1 19 33 57 66 71-74 83 137-142] The following sections examine this literature in more detail, focusing on studies that have assessed risk factors for HAIs at all sites and then studies that have focussed on risk factors for surgical wound, urinary tract, respiratory tract and bloodstream infections.

2.8.1 Risk factors for HAIs at any site

Studies that have examined risk factors for HAIs have identified a range of factors including age;[83] length of pre-operative stay;[19 83] severity of underlying illness as defined by factors such as diagnostic group, number of co-morbidities, the American Society of Anaesthesiologists score (ASA score), specific co-morbidities, and blood loss during surgery; type of admission,[37 57 83] practising surgeon,[33 74] malnutrition,[140] presence of devices such as central venous or urinary catheters,[33], and wound class (clean, clean contaminated, contaminated or dirty).

Some of the risk factors identified in these studies appear to be universally applicable to most patient populations, whereas others appear to be unique to the sample studied. Whilst in some cases this may reflect a genuine difference in the risk profile of the patients studied, in others it may simply reflect differences in the approach taken to assess risk factors for HAI, and, in particular, the range of explanatory variables included in the analysis.

As indicated above, studies have generally identified more than one risk factor for infection within a patient population. For example, a logistic multiple regression analysis of data collected for a Spanish prevalence study identified the following risk factors: the number of intrinisc risk factors (coma, renal failure

diabetes, hypoalbuminaemia, pressure sores, alcoholism, smoking and drug addiction); number of extrinsic factors (urinary catheterisation, peripheral vascular catheterization, central catheterisation with peripheral insertion, parenteral nutrition, tracheostomy and mechanical ventilation); baseline risk (three categories of clinical prognosis: severe, moderate and mild); length of stay prior to infection; and number of diagnoses. These factors were all found to be significantly associated with infection ($p<0.001$).[19] Interestingly whilst infections rates were found to increase with age, the results of the logistic regression indicated that age was not significantly associated with infection when other factors were taken in to account. In contrast an Italian prevalence study found that after controlling for a range of factors in a multiple logistic regression analysis, age was significantly associated with HAI, together with ward of stay, urinary catheterisation and receiving antibiotics.[37]

Another example is a study by Meltomaa *et al* (2000)[57] that assessed the risk factors for HAIs occurring in 687 women who underwent a hysterectomy at a University Teaching Hospital in Finland between October 1993-September 1994. The results of the multivariate analysis indicated five significant risk factors for an infection at any site: lack of antibiotic prophylaxis, blood loss during surgery of over 100mls (blood loss greater than 100 mls and less than 300 mls was associated with greater risk than blood loss in excess of 300mls, a situation which may have been due to patients with over 300mls of blood loss in some cases receiving a blood transfusion); intermittent catheterisation; anaemia; and post-operative administration of laxatives and cholinergic agents for urinary or bowel problems. However, when UTIs were excluded from the analysis, intermittent catheterisation ceased to be a risk factor.

2.8.2 Risk factors for surgical wound infections

Studies have identified a number of intrinsic and extrinsic risk factors for SWIs. Intrinsic risk factors include age, severity of illness,[66] [73] diabetes[66] wound class,[72] [73] infections at other sites prior to surgery,[139] malnutrition,[140] obesity[141] and weight loss of greater than 10% during the six months prior to surgery.[66]

Extrinsic risk factors include length of pre-operative stay,[62] [74] [83] the administration of a pre-operative shave,[62] [74] length of surgery;[62] [66] [73] [97] and the presence of prophylactic abdominal drains, which have been shown in both clinical and experimental studies to be associated with higher infection rates.

Mishriki *et al* (1990)[74] in a study of 702 adult, non- trauma patients assessed how the incidence of SWI rate varied with 23 potential risk factors: age, sex, pre-operative stay (days), current antibiotic treatment, co-existing diabetes, current immunosuppression, nutritional state, coexisting metabolic disease, pre-existing malignancy, preoperative shaving, prophylactic antibiotic treatment, type of skin preparation, duration of operation, operating surgeon, operating theatre, operation site, size of wound, type of wound closure, suture technique, use of deep tension sutures, type of wound dressing, use of surgical drains and main ward of stay (a modified data set was used for day cases). The authors selected these 23 factors as they had been shown in earlier studies to be related to SWIs. Of these 23 potential risk factors, only four were found to be significantly associated with SWIs: age> 55 in clean, clean-contaminated and dirty categories ($p = <0.05$); pre-operative stay > 3 days in clean-contaminated category ($p = <0.05$); pre-operative shaving in the contaminated group ($p=<0.005$); and individual surgeon in the clean category ($p=<0.001$). A forward stepwise regression analysis of ten independent variables was undertaken (age, preoperative stay, shaving, prophylactic antibiotics, skin preparation, surgeons, operating time, suture type, deep tension sutures, drains). It is not clear from the paper why these 10 were selected from the 23 possible variables. However, the results confirmed the univariate analysis although the overall contribution of these variables in the clean and clean–contaminated category was found to account for a small proportion of the overall variation. The association between surgeon and SWI had greatest significance. The elimination of a single surgeon's case load from the sample would have reduced the SWI rate by over 40%.

Garbaldi *et al* (1991)[73] assessed the risk factors for SWI in a study of 1852 adult surgical patients admitted to a university affiliated US hospital over a four year period from January 1982 to January 1986. Four independent variables which were highly predictive of SWI were identified from a stepwise logistic regression analysis of potential risk factors. These were wound class; ASA score; duration of procedure; and the results of an intra-operative culture However, the presence of intra-operative positive cultures had little explanatory power. The predictive power of a positive culture was low (32%) and the false positive rate was high (82%) and concordance with isolates from infected wounds low (41%).

A study by Kampf *et al*[142] utilised data collected as part of the first national prevalence survey conducted in Germany in 1944. The results of the multiple logistic regression analysis which included a number of variables found that the department (surgery or intensive care), age (>45 years), diabetes mellitus, male sex and size of hospital (> 600 beds) were significantly associated with SSIs.

2.8.3 Risk factors for urinary tract infections

The presence of a urinary catheter and the duration of catheterisation are key risk factors for this type of infection.[1 134 137 138 143 144] While 1% of non-catheterised patients will develop bacteriuria, between 10 and 30% of catheterised patients will develop bacteriuria and between 10 and 30% of these patients will develop symptoms of a UTI.[81] During the process of catheterisation bacteria may be introduced into the bladder, and following insertion, the bacteria may migrate from the peri-urethral area into the bladder, either through the catheter lumen or along the catheter – mucosal surface. Studies have indicated that the process of catheterisation is associated with a 1% risk of bacteriuria, and each subsequent day that the catheter is in situ there is a 3–10% risk of developing bacteriuria.[143 145] Following removal of the catheter, patients continue to remain at risk of acquiring an infection. For example, Harstein *et al* found that 11% of catheterised patients developed bacteriuria within 24 hours of the catheter being removed.[143]

Urinary catheters are frequently used in the care and treatment of patients in both the acute and long term care setting. A study of indwelling catheterisation and related nursing practice in adult patients admitted to specialties other than mental handicap, psychiatry or obstetrics at five district general hospitals in England found the prevalence of catheterisation was 12.6%.[146] Data from the US suggests that between 15 and 25% of patients in the acute care setting were catheterised. [81]

Catheterisation rates vary with specialty and from one care setting to another. The results of a recent audit of infection control policies and practices in 19 district general hospitals in England and Wales clearly demonstrates this.[1] The median catheterisation rate observed in adult patients admitted to selected specialties at 19 different hospitals, and who had a minimum in-patient stay of three days was considerably higher in patients admitted to the gynaecology specialty (40.4%: range 20.9% – 72.0%), when compared to the medical (11.6: range 5 –17%); surgical (34.4%: range 16.2-50.0%); and orthopaedic (17.3%: range 10.1 – 26.0%) specialties.

In addition to duration of catheterisation a number of other independent risk factors for UTIs in catheterised patients have been identified. A study of 1474 catheterised patients identified eight additional independent risk factors: absence of use of a urinemeter, microbial colonisation of the drainage bag, diabetes mellitus, absence of antibiotic use, female patient, indications for catheterisation other than drainage during surgery or output measurement, abnormal serum creatinine and catheter care violations.[138] More recently, Glynn *et al* (1997)[1] identified seven risk factors in addition to catheterisation: the risk was found to increase with increasing number of catheterisations, an ICD9 diagnosis other than endocrine diseases; female sex; transfer or emergency admission as opposed to elective admission, increasing age; and length of hospital stay. However, as pointed out by Glynn et *al* (1997) it was not clear whether longer length of stay was a risk factor for this type of infection or a result of the infection itself.

A study by Kampf *et al*[142] utilised data collected as part of the first national prevalence survey conducted in Germany in 1944. The results of the multiple logistic regression analysis which included a number of variables found that unconsciousness, old age (>75 years) prior operation, female sex and the size of the hospital (>200 bed) were all significant risk factors for UTIs. The authors argued that the first four risk factors were likely to reflect need for urethral catheterisation, which as indicated above, and acknowledged by the authors has been shown to be a key risk factor for this type of infection. With regard to hospital size they suggest that this may reflect the lower use of urine cultures in smaller hospitals, which can be critical to a diagnosis of UTI when using the CDC definitions.

2.8.4 Risk factors for lower respiratory tract infections

Specific risk factors for lower respiratory tract infections (LRTIs) include the presence of a nasogastric tube, mechanical ventilation, aspiration, specific lung disorders such as chronic airway disease and depressed consciousness.[1 147] However, as with infections at other sites the severity of the patient's condition will also have an impact on the risk of infection. The precise range of factors identified in these studies again varies from one study to another, which, as discussed above, may reflect both genuine differences in the risk profile of the population studied and/or the comprehensiveness of the methods employed to assess risk. For example, a recent audit of infection control in 19 hospitals in England and Wales identified the following risk factors for LRTIs occurring in adult patients admitted to medical and surgical specialties: the presence of a naso-gastric tube with the risk increasing with the number of days the tube was in place (1 day; 2 or more days); the presence of other devices with the risk again increasing with the number of days these were in situ (1 device, 2+devices); an ICD9 grouping other than endocrine diseases; four or more discharge diagnoses; sex with males at greater risk than females; age over 50; and length of stay with the risk of infection increasing with increasing length of stay (6-10 days , 11-15 days , 16+ days). In contrast Kampf *et al* (1998)[147] in their analysis of data from a prevalence study conducted in Germany identified

the following factors as being significantly related to the presence of a LRTI: polytrauma, impaired consciousness, chronic airway diseases, prior surgery and cardiovascular diseases. The differing results may simply reflect the fact that different explanatory variables were included in the analysis. For example, the study by Kampf *et al*[147] failed to include data on the presence of a naso-gastric tube, but included far more detailed information on diagnosis than the study by Glynn *et al* (1997).[1]

2.8.5 Risk factors for bloodstream infections

In addition to factors relating to the patient's underlying susceptibility to infection, a number of specific risk factors for BSIs have been identified in the literature including the presence of intravenous and central venous lines, invasive procedures, and the presence of infections at other sites – in particular the presence of a UTI.[1 148] Glynn *et al* 1997[1] in a multivariate analysis of data on adult patients admitted to 19 hospitals in England and Wales identified the following risk factors: the number of central venous catheters; the presence of other infections, an ICD9 diagnosis other than endocrine diseases (the reference category); three or more discharge diagnoses, and length of hospital stay, the risk increasing with increasing length of stay. However, as indicated above it was not clear from the results of their analysis whether the longer length of stay in infected patients acted as a risk factor for the infection or was a consequence of an infection acquired in hospital.

2.9 Risk indices

Based on the information derived from studies of risk factors for infection, composite measures of risk, based on a combination of risk factors, have been developed. These measures, described as risk indices, aim to control for the underlying infection risk of a patient population and thus facilitate the valid comparison of rates of HAI from one population to another. Risk indices have primarily been developed to assess the risk of acquiring a surgical wound infection, although some have also proved to be good predictors of infections at other sites.

For example, based on data from the US Study of the Efficacy of Nosocomial Infection (SENIC) Haley *et al* (1985)[149] developed a risk index for SWI. Of the ten potential risk factors for SWI included in the logistic regression analysis, four were found to be significantly associated with SWI: an operation involving the abdomen; an operation lasting over two hours; an operation classified as contaminated or dirty-infected based on the traditional wound classification system and three or more diagnoses on discharge (a proxy for intrinsic patient risk). In the final model all four risk factors had nearly equal coefficients. As such the risk index developed weighted all four risk factors equally, and patients were allocated to one of five groups based on the number of risk factors present: no risk factors, one, two, three and four risk factors.

The US NNIS surgical wound infection risk index, is an adaptation of the SENIC index.[67] Each surgical patient undergoing an operative procedure is allocated to a risk group based on how many of the following risk factors the patient had.

1. American Society of Anaesthesiologists (ASA) pre-operative score of 3, 4 or 5.
2. An operation classified as either contaminated or dirty-infected according to the traditional wound classification system.
3. An operation with duration of surgery more than T hours, where T depends on operative procedure performed.

The ASA score is an index designed to assess the pre-operative health status of patients. It ranges from 1 for an otherwise healthy patient to 5 for a patient not expected to survive the next two hours. Thus it is a slightly more detailed approach to assessing intrinsic risk than that used in the SENIC index of three or more discharge diagnoses. Furthermore it is assessing health status prior to surgery, whereas in the SENIC index assessment of health status is based on number of diagnoses at time of discharge from hospital, which in infected patients could be affected by the presence of an infection.

The NNIS index also differs from the SENIC index with respect to the information included regarding length of surgery. In the SENIC index there is simply a two hour cut off point: patients with surgery lasting more than two hours are considered to be at greater risk than patients whose surgery took less than two hours. In the NNIS index, only those patients whose surgery took longer than might be expected (T) are included. The 'T' value, as it is known, was determined from information on the distribution of duration of surgery for different operative procedures. The 75th percentile of each distribution was identified and rounded to the nearest whole hour and used as the cut off point for distinguishing between short and long duration. The T value identified in this way is thus a means of identifying surgery that is taking longer than usually expected. A study by Culver *et al* (1991) involving data on 84,691 operations performed on patients admitted to 44 NNIS hospitals during the period January 1987 through to December 1990, found the NNIS indices to be a better predictor of SWI risk than the traditional wound classification system.[67] It was also found to be a reasonable predictor of postoperative infections at other sites.[67] The application of this index elsewhere is widespread. However there are a number of important considerations. The T value was calculated from the distributions of duration of surgery in patients undergoing operative procedures within the NNIS scheme. It is questionable how accurately these reflect the distribution of duration of surgery conducted elsewhere and at different points in time. It is feasible that with the advancement of technology some procedures conducted today are carried out in less time. There is thus a need to question the validity of the T values prior to incorporating them in the index and if possible develop specific T values for the health care setting of interest.

The other issue to consider is that two of the risk factors, wound class and duration of surgery, are potentially also markers of quality of care. Consequently, adjustment for them in a comparative analysis of rates may mask rather than highlight a potential problem area.

2.10 The problem of microbial resistance to antibiotics and other antimicrobials

Microbial resistance to antibiotics is a problem which, at the time of their discovery in the late 1930s, was unimaginable. Antibiotics were viewed as the magic bullet designed to treat all infections, and they undoubtedly led to safer medical and surgical practice and increased life expectancy.[150] However, soon after their discovery problems relating to resistance developed as micro-organisms developed mechanisms to circumvent these drugs, and there is now the very real prospect of a post-antibiotic era.[151] Bacterial evolutionary responses to the selective pressure of antibiotics have resulted in micro-organisms resistant to virtually every known antibiotic. In 1941 virtually all strains of *S. aureus* were sensitive to penicillin. Within three years of its introduction several strains of *S. aureus* became capable of β lactamase production, enabling hydrolysis of the β lactam structure present in penicillin, thereby removing the drugs clinical efficacy.[150] In an endeavour to overcome this specific resistance problem, semi-synthetic penicillins were produced. Methicillin was the first such synthetic penicillin, but was superseded by a less toxic derivative, flucloxacillin, although methicillin is still used for in-vitro sensitivity testing as it has identical resistant patterns to those of flucloxacillin.[152] Soon after the drugs introduction methicillin resistant *S. aureus* (MRSA) developed,[153] and the frequency of isolation of this organism has increased steadily. MRSA strains are resistant to all penicillin derivatives and are in many cases resistant to other antibiotics. Vancomycin and teicoplanin are the only two consistently effective agents of use clinically.[150] Many other examples of antibiotic resistant micro-organisms can be cited. For example the global rise of vancomycin resistant enterococci (VRE), and multi-drug resistant *Mycobacterium tuberculosis* (MDRTB). A number of reports have documented the scale of the problem and situation.[154-160]

2.10.1 The development of antibiotic resistance

Antimicrobial resistance may be innate or acquired. Innate resistance refers to bacteria inherently resistant to one or more antibiotics. Many of these bacteria do not represent a threat to healthy humans, but may give rise to infection in hospitalised patients. Examples include the *Pseudomonas* species and some *Enterococci.*

Acquired resistance may develop as a result of mutations in a small proportion of a bacterial population. In the presence of the antibiotic to which it is resistant, the proportion of these altered bacteria multiply and become more dominant. For example, some mycobacterium *tuberculosis* are naturally resistant to the antibiotic streptomycin. In the presence of this antibiotic these bacteria soon become dominant in a population.

Acquired resistance may also develop through the transfer of genetic material encoding resistance from one bacterium to another. This can occur through the direct transfer of genetic material on plasmids, on a bacterial virus or a bacteriophage, or via the direct transfer of DNA. As before in the presence of antibiotics, the susceptible bacteria are killed, thereby selecting out resistant strains that subsequently become more dominant in the population.

More specifically antibiotic resistance develops through a variety of molecular mechanisms that pathogens have developed to circumvent antimicrobials. The House of Lords report on antibiotic resistance describes five broad mechanisms that give rise to antibiotic resistance: inactivation, where the bacteria can inactivate the drug before it reaches its target within the bacterial cell; impermeability, where the outer layers of the cell is impermeable preventing the drug from entering the cell; alteration of target site, where the target is altered so that it is no longer recognised by the antibiotic; efflux, where the drug enters the bacteria but is then pumped out; and by-pass where the bacteria acquire an alternative metabolic pathway resulting in the antibiotic's target being made redundant.[154]

Inappropriate prescribing is a key factor in the development of resistance. This includes the inappropriate use of antibiotics for self-limiting or viral infections such as colds, and some sore throats, and where antibiotics are justified, an inappropriate drug and/or treatment regime selected. The House of Lords Report on antibiotic resistance comments that in the UK, whilst the present use of antibiotics is conservative compared to that in other countries, between 5-50% of antibiotic prescriptions are inappropriate, the proportion varying with geographical location.[154] In the US it has been estimated that over half of the antibiotics prescribed are prescribed inappropriately; that is antibiotics are not indicated or they are incorrectly prescribed.[161] The availability of antibiotics over the counter in some countries also contributes to the situation, as does the failure of patients to complete a full course of antibiotics.

There is some evidence to suggest that the inappropriate use of antibiotics in animal husbandry is another contributing factor. Of particular concern is the use of antibiotics in low quantities as growth promoters. Antibiotic resistance may be transferred directly from animals to humans via the food chain, or resistance may be transferred from the communal bacterial populations of animals to the commensal bacterial populations of humans and this transferred resistance eventually evolving into human pathogenic forms.[154]

2.11 Conclusion

This chapter has examined the extent of the problem of HAI in terms of its frequency and distribution as measured by prevalence and incidence studies, the mortality risk associated with acquiring an infection in hospital, the aetiology of and risk factors for HAIs, and the problem of antibiotic resistance. It is clear from the literature that HAIs affect a substantial number of patients every year, and that acquiring an infection in hospital increases an individual's mortality risk and in some cases can directly cause death or substantially contribute to death. It is also clear that the risk of acquiring an infection varies considerably from one patient to another, and a number of risk factors for these infections have

been identified. Some are directly related to the patient's condition (intrinsic risk factors), whilst others relate to the process of treatment and care (extrinsic risk factors). The recognition of these factors provides valuable information that can then be used to plan care and treatment which aims to reduce the impact of these risk factors. It is also clear from the literature that microbial resistance to antibiotics is a growing problem and one that needs to be tackled now.

This thesis aims to provide more timely data on the incidence of HAI occurring in adult patients admitted to five surgical specialties common to most general hospitals. It also aims to identify independent risk factors for these infections, and provide some data on the impact HAI has on mortality risk in this patient group. The thesis will not examine the important area of antibiotic resistance. This was considered beyond the scope of both the underlying study and this thesis. The following chapter will consider the economic burden of HAI and the potential economic benefits of prevention.

CHAPTER 3
THE ECONOMIC EVALUATION OF HAI

3.1 Introduction

Economic evaluation is concerned with the assessment of the costs and consequences of alternative practices,[162] thus enabling the comparison of alternative interventions in order to obtain the maximum health gain for a given expenditure, or the lowest expenditure for a given health gain.

In the context of hospital acquired infection (HAI), it is clear from the preceding chapter that HAIs affect a substantial number of patients every year. Whilst it is unlikely that all infections can be prevented,[163] the evidence suggests that a proportion of these infections could be prevented through improvements in infection control practice.[164] Evidence from the study of the efficacy of nosocomial infection control (SENIC) conducted in the US indicated that hospitals with an organised hospital wide infection control programme which included intensive surveillance, the feedback of results to those who need to know, one infection control nurse per 250 beds and the involvement of an infection control physician or microbiologist, on average achieved a 32% reduction in infection rates over time.[11] This evidence informed guidance issued by the Department of Health in 1995,[9] which stated that about 30% of HAIs could be prevented through improvements in infection control.

More recently, the National Audit Office (NAO) in England conducted a survey of NHS hospitals in which they asked infection control teams (ICTs) whether they believed a 30% reduction in rates could be achieved in their NHS Trust: 39% thought this could be achieved, 49% thought the estimate was too high, and the remaining 12% either did not know or did not answer the question. The NAO survey also asked ICTs to estimate what proportion of infections they considered to be preventable in their Trust. The responses varied from less than 5% to over 35%. The average percentage reduction across all NHS Trusts, adjusted for the number of beds in the individual hospitals that

responded, was 15%.[3] Whilst this is a subjective assessment of the proportion of HAIs that are preventable, it does demonstrate that there is a strong belief that a proportion of infections can be prevented. Evidence from studies which have assessed the incidence of HAI overtime in response to various interventions provides harder evidence that a proportion can be prevented (see section 3.6.2).

Whilst it is clear that a proportion of HAIs can be prevented, the prevention of HAIs is not cost free. Economic evaluation is thus concerned with estimating the costs associated with these infections, and the cost of activities that aim to prevent infection and their economic consequences, thus providing valuable data which can contribute to decision making regarding the allocation of resources to infection control and their use.

This chapter considers the literature relating to the economic evaluation of HAI. It begins with an overview of the processes and techniques of economic evaluation and discusses these in the context of HAI. Studies that have assessed the economic burden of HAI and the benefits of investment in prevention activities will then be reviewed.

The literature reviewed was identified through a series of consecutive searches, carried out during the period 1993 – March 2003, using the computerised bibliographic databases Medline and PubMed, supplemented by reference follow up, hand searching of selected journals, and consultation with experts in the field. The search was limited to papers published in the English language during the period 1975 – March 2003, and further limited to studies conducted in the developed countries of Europe, Canada, Australia and the USA. As with the literature review reported in Chapter 2, the decision to limit the review to literature published from the mid 1970s onwards, was based on the fact the Study of the Efficacy of Nosocomial Infection was published at this time, representing the beginning of a period of renewed interest in HAI.

The search strategy involved the use of selected key words (thesaurus terms) and combining these with a number of "free text" words. The key words used were: *hospital acquired infection; nosocomial infections; health care associated infections; hospital-associated infections.* These were combined with the following "free text" words: *economic; burden; costs; resources; cost of illness; evaluation; length of stay.* The abstract of each paper was subsequently read and a decision made as to whether the paper was relevant to this review. Those papers that were concerned with methodological approaches to assessing the economic burden of HAIs and studies that specifically assessed the economic burden resulting from HAIs occurring in adult non-day case patients cared for in specialties common to most hospitals (medicine, general surgery, urology, care of the elderly, orthopaedics, gynaecology and obstetrics) were considered to be relevant. Papers that were limited to day case patients, children, or patients admitted to specialities not included in this study were excluded from the review.

References cited in papers that had not been identified through the computerised search were subsequently followed up and hand searches of the following journals were carried out: Journal of Hospital Infection; Infection Control; Epidemiology and Infection Control; American Journal of Infection Control, Infection Control and Hospital Epidemiology, Current Issues in Infection Control; British Medical Journal. Experts in the field were also consulted to identify grey literature such as project reports and policy documents of relevance to this review. Experts included microbiologists, infection control doctors, infection control nurses and health economists from the Central Public Health Laboratory Service, the London School of Hygiene and Tropical Medicine, the National Audit Office, and NHS Trusts in England. The published results of the study of the socio-economic burden of HAI, the study on which thesis is based, are not presented in this chapter, but presented in Chapter 4.

3.2 Economic evaluation

Economic evaluations take a number of different forms including the following approaches: cost of illness, cost-effectiveness, cost utility, and cost-benefit analysis. Drummond (1987), when describing the various techniques available, classifies them into two distinct groups based on whether they enable a partial or full economic evaluation.[162]

3.2.1 Partial economic evaluations

Economic evaluations which do not include a comparator and fail to include both costs and consequences may be considered partial evaluations. They may be limited to a description of the outcome, or the costs, or include both costs and outcomes but no comparator. Alternatively they may include a comparison of two or more alternatives but be limited to the analysis of the efficacy or effectiveness or alternatively the costs involved.

Cost of illness (burden of illness) studies are examples of partial economic evaluations. These studies are limited to an assessment of the costs associated with a particular illness. They aim to identify, measure and value the direct, indirect and intangible costs of a particular illness. The approach represents one of earliest forms of economic evaluation.[165] For example, Petty in the 17th century employed a human capital approach to assess policies such as moving people from inner London to Hampstead Heath to prevent them catching the Plague, and later in the mid-nineteenth century cost of illness studies were used to justify public health activities.[165]

Cost of illness (COI) studies became increasingly popular in the 1950s and 1960s,[166] following which their popularity declined with many questioning their value. In the past COI studies have been conducted to demonstrate the economic burden of a disease and thus facilitate comparison of the burden of different diseases and assist in decision-making regarding prioritising health care and the subsequent allocation of resource. However, it has been argued that data limited to the burden of disease has little value and may be

misleading. By definition these studies are limited to the cost of the disease and do not attempt to look at the potential effectiveness or cost of interventions to prevent or treat the illness, and the benefits that might result. As such COI studies do not provide direct guidance on the allocation of resources.[167]

Byford *et al* (2000) argue that without data on the costs and effectiveness of prevention activities informed decisions about the allocation of resources cannot be taken. The situation might arise when a decision is taken to allocate more resources to the treatment or prevention of a particular disease simply because it is more expensive than the others that are being considered. However, without knowledge of the cost of the activities being considered and their effectiveness the decision might result in additional resources being used for little health gain.[168]

Similarly illnesses which impose a relatively small burden, but are easily preventable may be overlooked. Byford *et al* (2000)[168] cite the example of phenylketonuria, a disease which has a relatively low incidence and imposes a relatively small burden on society, but which is easily preventable at low cost, resulting in substantial health gains to the individuals concerned. Byford *et al* (2000)[168] thus argue that the results of some COI studies may divert the attention of policy decisions makers away from areas where improvements and health gains can be made at low cost

However, despite these limitations, COI studies do provide valuable data. Whilst the results do not represent the net benefits of investment in a particular activity, they do represent the resources that might become available if the disease did not exist. As such the results represent the potential benefits that might arise in terms of costs avoided, if the disease could be eliminated. These data can subsequently be used in conjunction with data on cost and effectiveness of activities which aim to prevent the illness and the results used to inform policy. The results of COI studies can also serve to highlight the magnitude of a problem and the items that are most costly, so facilitating

managers' attempts to improve the efficiency of provision. They may also be influential in setting the agenda for policy initiatives and for initiating further evaluative studies.[169] In the context of HAI a review of the literature indicates that a number of COI studies have been conducted; these are reviewed in section 3.4.

3.2.2 Full economic evaluations

Economic evaluations that assess both the costs and consequences of two or more alternatives may be classified as full economic evaluations.[162] Cost-effectiveness analysis, cost utility analysis and cost-benefit analysis are all techniques that might be used in a full economic evaluation.

3.2.2.1 Cost–effectiveness analysis

This type of analysis involves the comparison of alternative activities, which produce health outcomes that can be measured in the same units. For example, it might involve the comparison of interventions whose outcome can be measured in terms of the cost per life year gained or in the context of HAI the cost per infection averted. Alternatively the results can be presented as life years gained (or the number of infections averted) per pound spent. This type of analysis therefore allows the comparison of interventions with differing costs and levels of effectiveness. Furthermore, providing the interventions considered have a common effect, this approach can be used to compare the costs and consequences of a range of different interventions

3.2.2.2 Cost–utility analysis

In this type of analysis the outcome is expressed in terms of utility thus reflecting the preferences individuals or society have for a particular set of health outcomes. It thus assesses outcomes in terms of quality of life with the frequently used measure being quality adjusted life years (QALY). Other alternatives include healthy years equivalent (HYE) and disability adjusted life years (DALY). The results of this type of analysis are expressed in terms of the cost per quality adjusted life year gained, cost per healthy year gained, or cost

per disability adjusted life year gained by undertaking one intervention instead of another. Providing utility measures can be developed this approach allows the comparison of a range of interventions, and their multiple effects. However, the approach is frequently hampered by difficulties in obtaining appropriate utility data.

3.2.2.3 Cost-benefit analysis

Cost-benefit analysis involves a monetary value of both the costs and the benefits of the interventions being considered. Thus this type of analysis can be used when outcomes can be measured in financial terms, and enables the comparison of alternatives whose outcome cannot be reduced to a single common unit of effect and interventions that produce multiple outcomes. In the context of HAI, the costs of a range of activities aimed at reducing the risk of infections could be examined and a monetary value applied to the outcome measure of the number of cases of HAI averted.

3.3 The economic evaluation of HAI

In 1992 Haley commented that the number of studies estimating the economic burden of HAI has increased sharply since the mid 1970s.[170] Since that time many more studies have been published. Many of these are partial evaluations adopting a cost of illness approach, whereas others have attempted a full economic evaluation adopting techniques such as cost effectiveness and cost benefit analysis. Economic modelling, utilising data from a variety of data sources, has also been conducted. Studies which have included an assessment of the economic burden of HAI are discussed in section 3.4 and those that have assessed the cost and benefits of investment in infection control are considered in section 3.5.

3.4 Estimates of the economic burden of HAI

As indicated above, a number of studies have assessed the economic burden of HAI. Tables 3.1 – 3.6 provide an overview of studies conducted since 1975 that have assessed the burden of HAI to the hospital sector and the estimates derived. Table 3.1 presents estimates of the economic impact of all types of HAI and Tables 3.2 – 3.6 present estimates of the economic impact of specific types of infection.

Table 3.1: An overview of studies that have assessed the impact of HAIs (all sites) on hospital length of stay and costs (1975-2002)

First author and date of publication	Year of study	Country	Types of patients studied	Type of hospital	No. hosps	No. HAIs included in analysis	Method of attribution	Characteristics used in matching	Additional days in hospital	Additional hospital costs
Haley (1980) [48]	1975	USA	All admissions	Not stated	1	120	Case control - exact match	Diagnosis code, operative procedure, hospital service, age	13.4	$1018
Haley (1980) [48]	1975	USA	All admissions	Not stated	1	58	Case control - close match	Diagnosis code, operative procedure, hospital service, age	16.1	$1224
Haley (1980) [48]	1975	USA	All admissions	Not stated	1	183	Comparative - unmatched	N/A	17.0	$1292
Haley (1980) [48]	1975	USA	All admissions	Not stated	1	183	Physician assessment	N/A	4.8	$576
Scheckler (1978) [171]	1978	USA	All admissions	Community teaching hospital	1	123	Author assessment*	N/A	3.0	$636
Haley (1981)* [172]	1975-6	USA	All admissions	Mixed	3	256	Concurrent	N/A	4.5	$590
Davies (1979) [13]	1978	UK	Orthopaedic	District general hospital	1	29	Case control	Sex, age, operation, diagnosis, Quetalet's index, smoking habits, social class	17.0	£775
Rubenstein (1982) [69]	1979	Israel	General surgical & orthopaedic	University affiliated	1	90	Case control	Sex, age within 5 (sometimes 7) years, pre-operative diagnosis, operative procedure, month of hospitalisation, post-op stay at least 7 days	7.9	$787
Coello (1993) [14]	1988	UK	General surgical, orthopaedic & gynaecology patients who had a surgical procedure	District general hospital	1	67	Case control	Primary features: first operative procedure & primary diagnosis. Secondary features: sex, age (+or - 10 years) surgical service	8.2	£1,041

Table 3.1- continued: An overview of studies that have assessed the impact of HAIs (all sites) on hospital length of stay and costs (1975-2002)

First author and date of publication	Year of study	Country	Types of patients studied	Type of hospital	No. hosps	No. HAIs included in analysis	Method of attribution	Characteristics used in matching	Additional days in hospital	Additional hospital costs
Vegas(1993) [173]	1990	Spain	General and digestive surgical patients	Not stated	1	52	Case-control	Primary features: primary diagnosis, operative procedure, surgical category (clean, clean-contaminated contaminated, dirty), age (+or – 5years and in one case 6 years). Secondary features; presence of neoplastic or endocrine disease, elective or emergency procedure, number of days (+or – 5 days) before infection with an invasive device in situ.	11.4	$4449
Erbaydar (1995) [61]	1992-/94	Turkey	General surgery	University tertiary hospital	1	223	Crude comparison	N/A	17.0	—
Erbaydar (1995) [61]	1992-94	Turkey	General surgical	University tertiary hospital	1	151	Case control	Age, length of pre-operative stay, presence of malignancy or diabetes, presence of Foley catheters or drains	10.6	—

Table 3.2: An overview of studies that have assessed the impact of hospital acquired UTIs on hospital length of stay and costs (1975-2002)

First Author and date of publication	Year of study	Country	Types of patients studied	Type of hospital	No. hospitals	No. HAIs included in the analysis	Method of attribution	Characteristics used in matching	Additional days in hospital	Additional hospital costs
Haley (1986) [11]	1975-6	USA	All admissions	Mixed	3	177*	Concurrent	N/A	1.0	$593**
Scheckler (1978)[171]	1978	USA	All admissions	Community hospital	1	35	Concurrent	N/A	0.6	$146
Davies (1979) [13]	1978	UK	Orthopaedic	DGH	1	9	Case control	Sex, age, operation, diagnosis, Quetalet's index, smoking habits, social class	13.0	£617
Rubenstein (1982) [60]	1979	Israel	General surgical & orthopaedics	University affiliated	1	90	Case control	Sex, age within 5 (sometimes 7) years, pre-operative diagnosis, operative procedure, month of hospitalisation, post-op stay at least 7 days	5.1	$510
Coello (1993) [14]	1988	UK	General surgical, orthopaedic & gynaecology pts who had a surgical procedure	DGH	1	36	Case control	Primary features: first operative procedure & primary diagnosis. Secondary features: sex, age (+or - 10 years) surgical service	3.6	£467
Hillan (1995) [54]	Not stated	UK	Patients who had a caesarean sections	University teaching hospital	1	65	Crude comparison of infected pts with pts with no febrile morbidity or infection	N/A	0.8	—
Tambyah (2002) [174]	1997-98	US	Adult patients scheduled to be catheterised for more than 24 hours taking part in a trial of different types of catheter	University teaching hospital	1	235	Concurrent	N/A	0***	$589

*Number of HAIs was taken from an earlier paper[45] where the actual number of HAIs was not clearly stated in the text
** Estimate based on the results of the study conducted in 1976 and adjusted by Haley for inflation to 1985 costs
***One patient developed a BSI secondary to the UTI had an extended LOS attributable to the UTI

Table 3.3: An overview of studies that have assessed the impact of hospital acquired SWIs on hospital length of stay and costs 1975-2002)

First author and date of publication	Year of study	Country	Types of patients studied	Type of hospital	No. hosps	No. HAIs included in the analysis	Method of attribution	Characteristics used in matching	Additional days in hospital	Additional hospital costs
Haley (1986)[11]	1975-6	USA	All admissions	Mixed	3	110*	Concurrent	N/A	7.0	$2734
Scheckler (1978)[171]		USA	All admissions	Community teaching hospital	1	26	Author assessment*	N/A	6.5	$1329
Rubenstein (1982)[69]	1979	Israel	General surgical & orthopaedic	Not stated	1	19	Case -control	Sex, age within 5 (sometimes 7) years, pre-operative diagnosis, operative procedure, month of hospitalisation, post-op stayat least 7 days	12.9	$1290
Mugford (1989)[175]	1987	UK	Patients who had a caesarean sections	University teaching hospital	1	41	Crude comparison of infected pts with pts with no febrile morbidity or infection	N/A	1.3	£716
Coello (1993)[14]	1988	UK	General surgical , orthopaedic & gynaecology pts who had a surgical procedure	DGH	1	12	Case- control	Primary features: first operative procedure and primary diagnosis. Secondary features: sex, age(+or -10 years) surgical service	10.2	£1,456
Poulsen (1994)[176]	1985-8	Denmark	Surgical	University teaching hospital	1	291	Case-control	Operation code, sex, age group	5.7	—
Hyryla (1994)[177]	1988-90	Finland	Surgical patients whose infection warranted compensation	All types	All	1100	Regression modelling	N/A	33.2	—
O'Donoghue (1992)[178]	1990	UK	Orthopaedic patients	DGH	1		Case control - outbreak of 10 serious wound infections occurring with 1-2 weeks of surgery	Sex, age (within 5 years), pre-operative stay, orthopaedic procedure performed, general health status prior to surgery.	17.0	£2,220

Table 3.3 continued: An overview of studies that have assessed the impact of hospital acquired SWIs on hospital length of stay and costs (1975-2002)

First author and date of publication	Year of study	Country	Types of patients studied	Type of hospital	No. hosps	No. HAIs included in the analysis	Method of attribution	Characteristics used in matching	Additional days in hospital	Additional hospital costs
Vegas(1993) [173]	1990	Spain	General and digestive surgical patients	-	1	30	Case-control	Primary features: primary diagnosis, operative procedure, surgical category (clean, clean-contaminated contaminated, dirty), age (+or – 5years and in one case 6 years). Secondary features; presence of neoplastic or endocrine disease, elective or emergency procedure, number of days (+or – 5 days) before infection with an invasive device in situ.	14.3	$5,617
Hillan (1995) [9]	not stated	UK	Pts who had a caesarean sections	University teaching hospital	1	42	Crude comparison of infected pts with no febrile morbidity or infection	N/A	3.6	—
Taylor(1995) [179]	1992	Canada	Surgical pts admitted to selected specialties who underwent clean or clean-contaminated surgery**	University hospital	1	68	Case-control	Risk-indexed procedure in the same surgical division	19.5	—
Kirkland(1999) [66]	1991-95	USA	Surgical	Community hospital	1	255	Case-control	Age, procedure, NNISS risk index, date of surgery, surgeon	6.5	$3089
Whitehouse (2002) [180]	2000	USA	Orthopaedic	University teaching hospital and a community hospital	2	59	Case -control	Type of operative procedure, NNIS risk index, age within 5 years, date of surgery within the same year, surgeon.	1.0	—

*This was based on physician's opinion and data on expected LOS given primary and secondary diagnosis, age, sex and service and date of onset and duration of HAI

** General surgery, orthopaedic surgery, thoracic surgery, neuro surgery, department of obstetrics & gynaecology patients

*** Initial period of hospitalisation.

Table 3.4: An overview of studies that have assessed the impact of hospital acquired LRTIs on hospital length of stay and costs (1975-2002)

First Author and date of publication	Year of study	Country	Types of patients studied	Type of hospital	No. hosps	No. HAIs included in the analysis	Method of attribution	Characteristics used in matching	Additional days in hospital	Additional hospital costs
Scheckler (1978) [171]	1978	USA	All admissions	Community hospital	1	17	Author assessment *	N/A	3.8	$878
Dixon (1978) [181]	Not stated	USA	All admissions	Mixed	Not stated	Not stated	Not stated	Not stated	4.0	$832
Haley (1986) [11]	1975-76	USA	All admissions	Mixed	3	64	Concurrent	N/A	6	$4947
Hillan (1995) [54]	not stated	UK	Pts who had caesarean section	University teaching hospital	1	23	Crude comparison of infected patients with no febrile morbidity or infection	N/A	2.5	—
Kappstein (1992) [182]	1988-89	Germany	Ventilated patients - ICU	University hospital	1	34	Case control	Reason for ventilation, age with 10 years; duration of ventilation therapy in controls and duration of ICU stay at least equal to the duration of ventilation therapy and ICU stay prior to the onset of infection	10.13 - ICU days	$8,800

This was based on physicians opinion and data on expected LOS given primary and secondary diagnosis, age, sex and service and date of onset and duration of HAI

** Estimate of the number of extra days patients with a LRTI remain in hospital was taken from a study reported in a paper published in 1978.[181]

Table 3.5: An overview of studies that have assessed the impact of hospital acquired BSIs on hospital length of stay and costs (1975-2002)

First Author and date of publication	Year of study	Country	Types of patients studied	Type of hospital	No. hosps	No. HAIs included in the analysis	Method of attribution	Characteristics used in matching	Additional days in hospital	Additional hospital costs
Wey (1988) [183]	1983-86	USA	All admissions	University teaching hospital	1	34	Case-control	Stage 1: Underlying disease, age, major surgical procedure, date of admission, sex. Stage 2: Scoring system based on characteristics used in stage one plus controls need to have he same period at risk. Stage 3: secondary diagnosis and surgical procedures. Stage four: Disease severity based on duration of underlying illness.	30.0	-
Pittet (1994) [113]	1998-1990	USA	Surgical intensive care	University teaching hospital	1	81	Case-control	Admission to surgical intensive care, primary diagnosis, age within 5 years, sex, LOS in controls equal to the number of days from admission to infection in cases (= or- 10%), number of discharge diagnosis.	14.0	£33,268
Pittet (1994) [113]	1998-1990	USA	Surgical intensive care	University teaching hospital	1	41 (survivors)	Case-control	Admission to surgical intensive care, primary diagnosis, age within 5 years, sex, length of stay in controls equal to the number of days from admission to infection in cases (= or- 10%), number of discharge diagnosis.	24.0	£40,890 (per survivor)
Orsi (2002) [121]	1994 – 95	Italy	Surgical	University teaching hospital	1	105	Case-control	Primary diagnosis, age within 5 years, sex, length of stay n controls equal to the number of days from admission to infection in cases (= or- 20%), number of discharge diagnosis, presence of central venous catheter.	19.1	16,356 Euro
Orsi (2002) [121]	1994 – 95	Italy	Surgical	University teaching hospital	1	105	Case-control	Primary diagnosis, age within 5 years, sex, number of discharge diagnosis, presence of central venous catheter.	19.9	—

Table 3.6: An overview of studies that have assessed the impact of multiple HAIs on hospital length of stay and costs (1975- 2002)

First Author and date of publication	Year of study	Country	Types of patients studied	Type of hospital	No. hospitals	No. HAIs included in the analysis	Method of attribution	Characteristics used in matching	Additional days in hospital	Additional hospital costs
Coello (1993)[14]	1988	UK	General surgery, orthopaedic & gynaecology who had undergone a surgical procedure	DGH	1	9	Case-control	Primary features: first operative procedure and primary diagnosis. Secondary features: sex, age(+or - 10 years) surgical service	26	£3,362
Rubenstein (1982)[69]	1979	Israel	General surgery & orthopaedics	Not stated	1	8	Case- control	Sex, age within 5 (sometimes 7) years, pre-operative diagnosis, operative procedure, month of hospitalisation, post-op stay at least 7 days	18	$1800

* This was based on physicians opinion and data on expected LOS given primary and secondary diagnosis, age, sex and service, date of onset and duration of HAI

The estimates presented in Tables 3.2-3.6 demonstrate that the estimated impact of HAI not only varies considerably with site of infection, but also with study. The observed variations can in part be attributed to methodological and case-mix differences. Methodological differences include variation in the range of costs included, the methods used to attribute resources to HAI, and the methods used to value resources. Other methodological differences relate to the definitions of HAI used, and the methods used to identify HAIs.

Variations in the case-mix studied include important differences in the types of patients studied and the treatment regimes received. For example, some studies include a broad case mix of patients whereas others focus on a particular patient group defined by operative procedure or specialty. Treatment patterns also vary with hospital and over time. For example, patients are discharged home at an earlier point in their recovery today than a few years ago. This changing treatment pattern will inevitably impact on the cost estimates derived and will prohibit valid direct comparisons between the results of studies conducted at different times.

Despite these important differences, some common themes emerge from the literature. Before considering these, some of the key methodological differences and issues that emerge from the literature will be discussed.

3.4.1 The range of costs resulting from HAI

The acquisition of an infection in hospital may have an impact on the costs incurred by the health care sector, community care services, affected patients, those who care for them, the economy and the environment. For example, HAIs may result in additional costs to the hospital sector, general practitioners, district nursing services, community midwifery services and a range of other health and community care services. Patients may experience an increase in personal expenditure on items such as drugs and dressings and incur financial losses due to a reduction in earning capacity as a result of delayed, or in some case a failure to return to work. Patients may also incur non-financial costs in

the form of a temporary or long term reduction in health status. Informal carers may also lose work or leisure time. Society may be affected also. Production losses may result from a delayed or non-return to work. Environmental costs may ensue as a direct consequence of efforts to treat HAIs, e.g. the treatment of HAIs may result in an increase in the use of dressings, which subsequently have to be destroyed, at a cost to the environment.[184]

The range of costs to be included in an evaluation of the burden of HAI will depend on the viewpoint to be taken. If a societal viewpoint is adopted than all costs should be included, whereas if the viewpoint of the health service is adopted then the range of costs may be limited to those that impact on the health service. Studies that have estimated the economic burden of HAI tend to limit the range of costs included to those that fall on the hospital sector as a result of additional in-patient care. Haley (1992)[170] suggests that this deficiency is perpetuated by the use of economic studies to persuade hospital managers of the financial importance of infection. There are however a few exceptions. Davies and Cottingham (1979)[13] in their study of HAIs occurring in orthopaedic patients, included the impact of infection on primary health care services, and Elliston *et al*[185] in a small study involving 71 patients who had a surgical wound, examined the incidence of SWIs presenting after discharge and their impact on community health care services Kirkland *et al* (1999)[68] in their study of SWIs occurring in surgical patients admitted to a hospital in the US extended their cost analysis to include the costs associated with re-admission to hospital within 30 days of discharge. Hyryla *et al* (1994)[177] considered the implications of HAI for the Finnish social security system; Poulsen *et al* (1994)[176] examined the impact of HAI on the Danish social security system; Persson *et al* (1988)[186] included a value for the loss of health suffered by patients as a result of an HAI; Fabry *et al* (1982)[10] examined whether SWIs delayed the time of return to work; and Dashner (1989)[184] has examined the environmental consequence of selected treatment interventions.

3.4.2 Attributing resources to HAI

McGowan (1982) notes that attributing resources and their associated costs to HAI is difficult.[187] Studies have generally used one of three key methods to attribute costs to the presence of infection: the concurrent method, comparative method and comparative method with matching (see Haley *et al.,* 1980; McGowan, 1981; McGowan, 1982; and Haley, 1992 for a detailed discussion of these methods).[48 170 187 188]

With the concurrent method a suitably qualified individual reviews patient records and identifies which resources were used as a result of an infection. Given the subjective nature of assessment of resources attributed to infection the validity and reliability of the approach has been questioned.[187] It has also been suggested that physician reviewers may be reticent about attributing the use of resources to HAI, and as such costs are likely to be underestimated.[48]

To a degree some of these criticisms were overcome in a study by Wakefield *et al* (1987).[189] Trained personnel reviewed medical records, using a carefully prepared protocol -'the appropriateness evaluation protocol' - to assess whether each in-patient day was (a) attributable to the reason for admission, (b) jointly attributable to the reason for admission and the HAI, or (c) attributable to the HAI alone. This approach has been found to be both repeatable and valid.[190-192] However, the approach is dependant on detailed and accurate hospital records being available.

The comparative method involves assessing the cost of resources used by infected and uninfected patients, and then attributing the differences between the costs observed to the presence of an infection. This method therefore assumes that the two groups (infected and uninfected patients) are the same in all respects except for the presence or absence of an HAI. This is clearly not the case. There may be many factors, other than HAI, which differ between these two groups and which also have an impact on resources used.

The comparative method with matching attempts to control for factors other than HAI that might differ between the two patient groups. Infected patients are matched with one or more uninfected patients on the basis of factors thought to have an impact on resource use. Studies have generally matched patients using a combination of the following factors: age, sex, diagnosis, number of co-morbidities and type of operation (Tables 3.1 – 3.6). The resources used by patients and controls are then compared, and the differences in costs attributed to the HAI. Haley (1991) notes that it is important that the differences between the cost incurred by infected and uninfected patients are first determined for individual patients, and then either summed (or averaged) to determine the total (or average) costs attributable to infection. Haley (1991)[193] notes that a common mistake in studies of this type is to break the matching, and simply compare the total costs incurred by infected patients, to cost incurred by uninfected patients. This approach is invalid and may lead to biased estimates of the costs attributable to HAI.

This comparative method with matching approach is hampered by practical difficulties associated with finding suitable control patients. Many studies have been unable to match all infected patients with uninfected controls. Haley *et al* (1980)[48] in a review of matched studies conducted between 1953 and 1975, found considerable variation in the percentage of infected patients successfully matched with uninfected patients. Successful matching of infected patients with uninfected patients ranged from a low of 32 per cent to 100 per cent. Scheckler *et al* (1978)[171] in a study to assess the economic burden of HAIs occurring in 104 patients admitted to a community hospital in the US between January and March 1978, was unable to find a sufficient number of suitable controls and as such had to abandon this approach to attribution of costs. Rubenstein *et al* (1982)[69] in a study involving 152 infected general surgical and orthopaedic patients was only able to find suitable controls for 59% of patients. A similar proportion of infected patients were successfully matched in a study by Kappstein *et al* (1992)[182] which assessed the excess costs and LOS resulting from ventilator associated pneumonia occurring in patients admitted to the

intensive care unit of a University Teaching Hospital in Germany. Kappstein *et al* found that after excluding cases that died during their admission, suitable controls could only be found for 34 of the 57 cases (60%). A more recent study, conducted in the UK, successfully matched 67 (85%) of the 79 infected surgical patients for whom medical records were available for review,[14] whereas a study conducted in Turkey in 1994 involving general surgical patients successfully matched only 67% of their 225 infected patients.[61]

Freeman (1979)[111] notes that the ability to find matched uninfected patient depends on the size of the pool of uninfected patients and the number of matching characteristics. The absence of a suitable pool of uninfected patients may necessitate a reduction in the number of matching parameters, thus reducing the comparability of the infected and uninfected groups, and/or the exclusion of unmatched infected patients from the analysis, which in some cases, may limit the analysis to an un-representative subset of infected patients. Both responses may have an impact on the accuracy of the estimates of the costs attributable to HAI.[193]

In 1980 Haley *et al* (1980) compared the concurrent and comparative method by using both to study the same population.[48] Haley found that the closer the matching the lower the estimate of the number of additional days attributable to infection. However, regardless of the level of matching the comparative method appeared to overestimate the number of days attributable to HAI compared to the results derived using the concurrent method. At the same time it was acknowledged that the concurrent method may underestimate the cost of HAI. The physician-epidemiologist tended to attribute extra days to HAI only if they were clearly the consequences of a HAI.

Haley (1991) suggests that one of the problems with studies utilising the comparative approach is that matching parameters such as age, sex, service, first diagnosis and first operation do not adequately control for differences between infected and uninfected patients which may have an impact on

resource use.[193] Matching should ensure that prior to the acquisition of an infection, infected and uninfected patients have the same predicted length of stay and level of resource use. Haley argues that diagnostic related groups are the best predictor of length of stay, and that this should be included in such studies, together with the number of discharge diagnoses. This latter measure increased the predictive power of the diagnostic group on length of stay and level of resources used. Together these factors have been found to explain 34% of the variance in length of stay.[193]

3.4.3 Estimating the cost of resources attributable to HAI

Economists measure costs as the benefit forgone by using resources in one way rather than in another, more precisely the next best alternative use. In the context of HAI, it is probable that resources used to care for patients with an HAI would, in the absence of the infection, have had alternative uses. The benefits forgone represent the opportunity costs of HAI.

Deriving estimates of the opportunity costs of HAI presents a number of difficulties. The most common method to estimate the value of resources used in one way, as opposed to another, is by applying monetary prices. However, prices will only approximate the opportunity costs if markets are 'perfect'. For a number of reasons markets are not 'perfect.' For example there are problems associated with uncertainty, imperfect information, externalities and the number of firms given size of the market.[194] Furthermore, few health care systems generate prices and when they do, for example charges in the US health system, they may not reflect the cost of resources. For example, cost shifting may be present as a result of hospitals shifting their charges for under-reimbursed costs to those payers with which they can recover more than their costs.[170 195] To overcome these difficulties some studies, particularly those conducted in the US, have applied a cost-to-charge ratio in an endeavour to convert charges to costs. This measure is generally the ratio of the sum of the total hospital expenditure per annum to the sum of patient charges per annum. The cost-to-charge ratio typically lies between 0.6 and 0.8.[193] This approach

overcomes some of the bias associated with applying charges, however the estimate derived is a somewhat crude estimate of total costs attributable to HAI, and as a result of cost shifting, may not be accurate for individual patients and departments.[193] This latter criticism can be overcome to a degree by stratifying the resources and associated charges attributable to HAI by individual departments, and applying a department based cost-to-charge ratio to these charges.

Dawson (1994) argues that the costs derived from the UK health sector are usually the result of mechanistic accounting conventions designed to recover expenditure rather than reflect resource use.[196] For example, the allocation of overheads and capital charges are made by convention. These costs are a significant proportion of total costs.[197]

In many studies average unit costs are applied. For example, the number of additional days a patient with an HAI remains in hospital is determined and an average cost per bed day applied. This approach may also introduce bias into the estimates derived. Average costs are a function of the total quantity produced. Thus if the cost per day in hospital is considered, the average cost per bed day is a function of the total number of bed days produced. Average cost estimates derived from hospitals operating at different levels of capacity will therefore differ. Furthermore daily costs will differ over the period of hospitalisation. For example, Hollingsworth *et al* (1993) found that patients admitted to hospital with a fractured neck of femur incurred relatively high daily costs during the first few days in hospital, after which they decreased.[198] This pattern of daily costs is likely to vary with type of patient and in patients who acquire an infection in hospital.

An alternative approach to those identified above is the cost accounting approach, or what Haley (1991) has described as `micro costing.'[193] This involves determining the actual cost of delivering the identified services. This

approach provides more accurate and valid estimates of the costs attributable to HAI but is time consuming, costly and difficult to conduct.

3.4.4 Alternative measures of the impact of HAI

An alternative measure of the impact of HAI on resource use is the number of additional days patients remain in hospital as a result of HAI. Haley argues that this is a harder measure of the cost of HAI as it is subject to less variation from year to year than charges which are subject to inflationary pressures.[170] [193] Studies generally provide estimates of both the number of additional days in hospital and the costs incurred. A few studies have also presented data on the number of antibiotic days and the number of investigations.[14]

3.5 Estimates of the economic burden of HAI to the hospital sector

As indicated above the estimates of the economic burden of HAI presented in Tables 3.1 – 3.6 vary considerably with the site of infection and also within any site specific category. Whilst in part this can be attributed to methodological and case mix differences some common themes emerge from the literature and are discussed below.

3.5.1 Estimates of the cost of specific types of HAI

Infections of the urinary tract are generally the least expensive, whereas the more costly infections tend to be infections of the bloodstream, chest and infections at more than one site. This is clearly demonstrated in the few studies that have assessed the cost of different types of infection occurring in the same patient population. A US study which estimated the impact of HAIs at differing sites occurring in patients admitted to three hospitals in the US in 1975/6 found that on average UTIs increased the patients LOS by one day (additional cost $594); pneumonia increased the patients LOS by six days (additional cost $4,947); BSIs - seven days (additional cost $3,061) and SWIs seven days (additional cost $2,734).[11].

Data from a UK study of 67 surgical patients with an HAI estimated the cost per UTI to be £467, SWI £1,454 and multiple infections £3,362. On average UTIs extended the hospital stay by 4 days, SWIs 10 days and multiple infections 26 days.[14]

Overall the results presented in Tables 3.2-3.6 indicate that there are marked variations in the estimates of the impact of different types of infections on the hospital sector. Estimates of the number of days that may be attributable to a UTI vary from 1 to 13 days. In contrast estimates of the impact of SWIs on hospital LOS range from a low estimate of 1.3 additional days in a study limited to women who had a caesarean section[175] to 33.2 additional days in a study which involved patients whose infection warranted compensation from the Finnish Social Security system.[177] Estimates of the impact of BSIs on hospital LOS range from 7 to 14 extra days, and estimates of the impact of chest infections vary from 2.5 to 10.3 additional days. Finally estimates of the impact of HAIs at more than one site vary from 18 to 26 additional days.

3.5.2 *Estimates of the cost of HAIs occurring in selected patient groups*

Costs have also been found to vary considerably with patient group. This may reflect differences in the type of infection occurring in the selected patient group, which in turn have different resource implications, and/or the implications of the infection for resource use in the selected patient group. Infections occurring in intensive care patients have been found to be particularly resource intensive. For example, Pittet *et al* (1994) estimated that BSIs occurring in ITU patients cost $40,000 per survivor.[113] Amongst the surgical specialties, infections occurring in orthopaedic patients also appear to be particularly costly. Coello *et al* (1993) estimated the average cost per HAI occurring in orthopaedic patients to be £2,646. This compared to £1,365 per HAI occurring in general surgical and urology patients, and £404 per HAI occurring in gynaecology patients.[14]

3.5.3 *The distribution of the additional hospital costs resulting from treating HAIs*

Some studies have attempted to disaggregate the cost estimates derived and have examined the distribution of the in-patient costs. For example, Coello *et al* (1993) estimated the costs associated with an extended length of hospital stay, antibiotics, microbiology tests and radiological investigations: 93% of the total additional cost incurred by surgical patients with an HAI could be attributed to an extended length of stay.[14] A number of other studies have also looked at the distribution of costs, but as with the study by Coello, they have generally limited the distribution of costs to those linked to time in hospital, antibiotics, microbiology tests and x-rays (e.g. Davies and Cottingham, 1979; [13] Wakefield *et al.*, 1987)[189]

3.5.4 *The national burden of HAIs*

National estimates of the burden of HAI are also presented in the literature. In the US HAIs have been estimated to cost the hospital sector $4 billion,[12] and in a paper by Losos *et al* (1984)[199] the direct and indirect costs of HAIs affecting patients in Canadian acute care hospitals were estimated to be between $300 and $1billion depending on the estimates of incidence and excess length of stay used.

In the UK, in 1981 a crude estimate of the additional costs of HAI was presented in an editorial in the Journal of Hospital Infection.[200] Based on the assumption that HAIs extend LOS by at least three days; the average cost per day in hospital is £50; and 5% of patients acquire an infection in hospital, it was estimated that HAIs were costing the hospital sector in England alone at least £30 million per annum.

In 1988, a Joint DHSS/PHLS working group derived an estimate that was considerably higher. It was estimated that in England 950,000 bed days were lost per annum, at a cost to the NHS of £111 million.(DHSS/PHLS, 1988) This figure was derived using what Haley has termed the `back of the envelope

approach' or crude weighting.[170] It was assumed that 5% of patients acquire an infection in hospital and this, on average, extends the hospital stay by four days. These assumptions were then applied to the total number of admissions to NHS provider units in England and an estimate of the number of bed days lost, and costs incurred, based on an average cost per day, derived.

In 1993 Coello *et al*[14] based on the results of a study examining the burden of HAI occurring in surgical patients admitted to one district general hospital estimated that HAIs occurring in surgical patients alone cost NHS hospitals in England, £170 million per annum.

As indicated above the overall cost to the hospital sector is a function of both the cost per case and the incidence of HAI. Data from the US indicates that although UTIs account for 45% of HAIs, they only account for 13% of the additional costs incurred, whereas pneumonia accounts for 19% of HAIs, but accounts for 39% of the additional costs and SWIs account for 29% of HAIs, but account for 42% of the additional costs. BSIs account for 2% of HAIs, but 4% of additional costs.[11]

3.6 Assessment of the benefits of prevention

Studies that have assessed the benefits of prevention vary considerably in scope and study design. They can be broadly categorised into those that have assessed the gross benefits of prevention, that is they have not taken into account the costs of achieving a reduction in rates; those that have taken into account the costs of prevention and assessed the net benefits of prevention; and those that have looked at the cost of carrying out selected ineffective 'prevention' activities.

When evaluating an economic study Drummond (1987)[162] suggests that the evaluator should consider ten key questions which aim to identify the presence or absence of ten methodological features of a well conducted economic study. However, in the context of studies that have assessed the costs and benefits of

infection control practices, Drummond[201] suggests that the following six areas are of particular relevance and should be considered in any assessment: the viewpoint selected; the alternatives selected for comparison; the range of costs and benefits considered; how costs and benefits were assessed; whether incremental analysis was conducted; and whether the evaluation included sensitivity analysis.

As in any economic evaluation a choice of viewpoints can be selected, ranging from a very broad viewpoint such as that of society, to a narrower viewpoint such as the health sector, the hospital sector or the infection control team itself. The majority of studies reported in the literature take the viewpoint of the hospital sector and neglect costs and benefits falling elsewhere.

The alternatives selected will clearly depend on the focus of the study. However, as pointed out by Drummond[201] it should be noted that one of the problems facing such economic evaluations is that infection control practices tend to be complementary – they do not work in isolation. As such it is difficult to tease out the costs and benefits of a particular infection control practice. An exception is those studies that have assessed the costs and benefits of selected prophylactic antibiotic regimes. These studies tend to be part of a randomised controlled study, designed to control for factors other than the presence or absence of the drug that might impact on infection rates.

The range of costs and benefits included to a greater extent will depend on the viewpoint adopted in any given study. As indicated above this tends to be the hospital sector and as such the range of costs and benefits tends to be limited to those experienced by the hospital sector

The methods by which costs and benefits are assessed are clearly of great importance. This includes how the costs associated with the intervention are identified and valued and how avoided costs, that is the costs of infections averted are identified and valued. The methods by which the costs are

identified, attributed to HAI and valued will have implications for the reliability and validity of the results obtained.

Incremental analysis is also important. Incremental analysis provides important data on how much should be invested in infection control practice. It allows for the determination of the most economically optimal level of control, such that any additional investment in infection control will result in costs greater than the benefits that are likely to result, and any less investment will result in benefits greater than the costs of achieving a lower infection rate. Drummond[201] makes reference to a study by Persson *et al* (1988),[186] which assessed the costs and benefits of antibiotic prophylaxis in patients undergoing total hip replacements, and adopted this approach to the analysis of data.

Testing the sensitivity of study results to underlying assumptions is also important. Economic evaluations frequently include a number of assumptions, and the robustness of the results to changes in the parameters used in the study should be assessed. Drummond[201] makes reference to a study by Weinstein *et al* (1986)[202] in which assumptions about the range of clinical practices and costs were subjected to sensitivity analysis.

3.6.1 Estimates of the gross benefits of prevention

The results of the recent NAO survey of ICTs at acute NHS Trusts in England indicated that ICTs believed that a proportion of infections could be prevented. Estimates of the proportion of infections that could be prevented through improvements in infection control varied with NHS Trusts. After adjustment for the number of beds at each hospital, the results of the survey indicated that on average ICTs believed that a 15% reduction in infection rates could be achieved (bed weighted average). Applying this figure to the most recent estimate of the national burden these infections place on the health sector in England, the NAO estimated that a 15% reduction in infection rates would result in the release of resources valued at £150 million.[3] This estimate represents the gross benefits of prevention. The net benefits of prevention would be dependent on the costs of achieving a reduction in rates.

3.6.2 Estimates of the net benefits of prevention

Studies that have estimated the net benefits of prevention can be broadly categorised into those that have assessed the benefits of an effective infection control programme, those that have focussed on the costs and benefits of prophylactic antibiotics; and those that have assessed the costs and benefits of selected infection control practices. The approach adopted in these studies varies, with some utilising economic modelling techniques and others, particularly those concerned with assessing the costs and benefits of alternative prophylactic antibiotic regimes, utilising a randomised controlled trial study design.

3.6.2.1 Studies that have assessed the benefits of an effective infection control programme

A number of US estimates of the potential benefits of investing in an infection control team and programme are presented in the literature. In 1975, the US Centre for Disease Control estimated the cost and benefits of an infection control programme implemented in a 250 bed hospital. These estimates were subsequently revised in 1979, and further adjusted to 1985 prices in 1986.[11] The cost of establishing and maintaining an infection control programme in 1985 prices was estimated to be $60,000. This estimate includes the cost of employing an infection control nurse, a part time physician consultant, half-time clerical support, consumables and the cost of overheads. Earlier work indicated that HAIs cost the average 250 bed hospital $1 million per year. Consequently a 6% reduction in the costs associated with infection would pay for the cost of the infection control programme and any further reductions would result in greater returns for the investment.

Dixon (1987)[203] presents a similar hypothetical model of the costs and benefits of infection control in the US. The model relates to a hypothetical 250 bed hospital, with 12,000 adult and paediatric admissions per year. Based on the findings of the SENIC study Dixon estimated that in the absence of an effective infection control programme this hypothetical hospital would have an estimated

713 HAIs per year; whereas in the presence of an effective programme there would be an estimated 487 HAIs per year. Estimates of the costs of these infections were subsequently made, utilising data from an earlier study by Dixon in 1978.[181] The results indicated that HAIs occurring in a hospital without an effective infection control programme would cost the hospital sector in terms of excess charges an estimated $800,000 per year, whereas the cost in hospitals with an effective programme would be $550,000: a cost saving of $250,000 per year. Dixon subsequently estimated the cost of an effective infection control programme, to be $60,000. When these costs are taken into account, the net savings to the hospital per year were estimated to be $190,000. Dixon acknowledges that these estimates are crude. In reality the level of savings may vary considerably. However, he points out that the costs used in his model were conservative estimates of the economic burden of HAI and as such the actual savings could be more substantial. He also notes that the estimates used were average costs estimates. As such in a hospital that treats a greater proportion of high risk patients or provides high tech care, the costs savings may again be greater than estimated in his model. Finally he notes that the estimates of incidence and the level of HAIs that can be prevented were taken from the SENIC data derived in 1976. The SENIC study found that incidence rates were increasing in hospitals without effective programmes and falling in hospital with such programmes. As such again the benefits might be greater in some hospitals. However, in other cases the estimates may be over estimates. For example, the potential for reducing HAIs rate may be lower in some hospitals as a result of a low risk case mix.

In 1994, Wenzel presented a similar model of the costs and benefits of investment in infection control programmes as part of a lecture at the 3rd International Conference of the Hospital Infection Society.[204] Based on a number of assumptions, about the cost of an effective infection control programme, the number of admissions per annum to a 250 bed hospital, the incidence of HAI and the impact these infections have on length of hospital stay and costs, Wenzel demonstrated that depending on whether the incidence of

HAI was 10% or 5%, the costs of the programme would be re-cooped if 12.5 to 25% or infections were prevented. It should be noted that the costs of infection included in this model were limited to the marginal costs estimated to amount to $84,000. If the full costs of hospitalisation had been included in the cost estimates, estimated at $2.52 million, the proportion of infections that would need to be prevented to cover the cost of the infection control programme would be substantially reduced. If a wider cost perspective was taken, such that costs incurred by the health service post-discharge and the cost to the patients and carers were included the proportion of infections that would need to be prevented to cover costs would be lower still.

Wenzel (1995)[204] also presented estimates of the cost per life year gained as a result of effective prevention activities. These estimates were derived from a hypothetical model incorporating data on the cost of an infection control programme in 250-bed hospital, and incidence, mortality and attributable mortality rates. The results indicated that if it could be assumed that the quality of life of those patients who would have died from an infection if it had not been prevented was excellent, the cost per year of life saved compared favourably with the cost per life year saved as result of other preventative programmes, and the cost per quality adjusted life year of other programmes. Furthermore. Wenzel argued, that even if the quality of life year was only a small proportion of 100% or if the programme costs were considerably higher that those estimated in the model, infection control would continue to compare favourably to other programmes and as such was one of the most cost effective prevention activities. However, it should be noted that this model assumes that infections that directly cause mortality are preventable. It is not clear how preventable such infections are or how costly prevention of such infections would be. Further work is perhaps required to refine such a model and apply it to a specific situation such as a particular type of infection occurring in a defined patient group. However, despite this limitation, the models presented in the paper by Wenzel (1995) provide valuable insight into how cost and mortality

data can be used in conjunction with other data variables to demonstrate the potential benefits of investment in infection control.

An economic model developed by Miller *et al* (1989)[205] also demonstrates the benefits of investing in an effective infection control programme. The model incorporated data on admission and infection rates at the University of Virginia Medical Centre in the US in 1985, hospital charges associated with infections and the likely level of effectiveness of an infection control programme as defined by the SENIC study. Based on this data, Miller *et al* (1989) estimated that in 1985, the infection control programme which, with the exception of reporting back surgeon specific rates, met the criteria for a very effective programme as defined by SENIC, generated income amounting to $2,401,709.

In the UK Currie *et al* (1989),[206] assuming the national burden of HAI amounted to £111 million (based on an earlier Department of Health estimate) estimated that a reduction in the incidence of HAI by 20%, 32% and 50%, after offsetting the costs of the infection control teams and their programmes, would produce annual savings of £15.6 million, £29.3 million and £50 million respectively to the NHS.

3.6.2.2 Studies that have assessed the costs and benefits of antimicrobial prophylaxis

A number of studies have assessed the costs and benefits of antimicrobial prophylaxis,[175 186 207-212] and a review article by McGowan (1991) [213] discusses issues relating to the assessment of the costs and benefits of this form of prevention. Many of these studies have found that the benefits, measured in terms of a reduction in the incidence of HAI and the associated costs, outweigh the costs of the intervention, although the level of benefits differs with alternative regimens.[186 211 213] For example, Shapiro *et al* (1983)[207] examined the costs and benefits of antimicrobial prophylaxis in abdominal and vaginal hysterectomy. The use of the prophylactic antibiotics was found to reduce costs by $102 and $492 per patient respectively. However, the authors note that

these savings would be lost if more expensive antibiotics had been used (unless they were more effective), and if the duration of administration was extended. Mugford *et al* (1989)[175] examined the costs and benefits of prophylactic antibiotics administered to patients undergoing caesarean section. Data on the effectiveness of prophylactic antibiotics were obtained from 58 controlled trials, and estimates of the costs associated with the alternative antibiotic regimens, and the costs of treating infections if they occurred were derived locally. The administration of prophylactic antibiotics was associated with a significant reduction in the incidence of SWI and a reduction in health care costs. Expenditure on prophylactic antibiotics was more than compensated for by the savings that resulted from a reduction in the incidence of HAIs and the associated treatment costs.

Persson *et al*(188)[186] examined the use of prophylaxis in total joint replacement surgery. Four approaches were considered, both in isolation and combination: systematic antibiotics, polymethylmethacrylate cement impregnated with gentamicin; surgical enclosure, exhaust ventilated suits. This study is interesting in that it did not simply look at the costs to the hospital sector, but also assigned a value to the effects of loss of health. The authors argue that the selection of an appropriate prophylactic regime should not be solely based on reducing costs to the hospital sector. The inclusion of a variable representing the value of loss of health, produced an economic optimum that allowed selection of a more costly regime and subsequently further reductions in infection rates and the need for re-operation.

3.6.2.3 Studies that assessed the costs and benefits of specific prevention activities

In addition to the above some studies have assessed the costs and benefits of specific infection control practices. For example, O'Donoghue *et al* (1992)[178] assessed the costs and benefits of procedures introduced to curtail an outbreak of ten serious surgical wound infections occurring in orthopaedic patients that occurred within 1-2 weeks of surgery. The cause of these infections was

thought to be five damaged mattresses, found to be colonised with *S.aureus, E.faecalis*, coliforms and *Pseudomonas* species, which were subsequently replaced. The costs of this intervention was assessed and compared to the cost of the infections, through a retrospective case control study. The ten SWIs were estimated to cost the hospital sector £22,199. The cost of replacing the mattresses was just £182.

A study by Lynch *et al* (1992) [65] assessed the cost and effectiveness of using chlorhexidine detergent in pre-operative whole-body disinfection as a means of preventing SWIs. The results of their randomised controlled trial, conducted between April 1987 and December 1999, indicated that whilst the SWI infection rate was lower in patients who used the chlorhexidine body wash than that observed in patients who received the placebo, the difference was not significant at the 0.05 level of significance, and there was no significant difference in the costs of treating infected patients in the placebo or treatment group.

Slater *et al* (2001)[214] estimated the potential savings of employing a vascular catheter-care specialist nurse for the surgical ICU within a US hospital, as a means of tackling the problem of catheter associated BSIs. The costs of employing the nurse were compared to the potential savings that might accrue if one infection per month was prevented. The potential benefits in terms of the estimated value of resources released if one infection per month was prevented were found to be greater than the costs of employing the nurse. A specialist nurse was subsequently employed. Within nine months of employment 18 fewer BSIs than the previous year had been identified. Assuming that on average each bloodstream infections utilises hospital resources valued at $6,000 per infection, this represented gross savings estimated at $108,000 and estimated net savings of at least £58,000.

Plowman *et al* (2001)[215] developed a model for estimating the costs and benefits associated with the routine use of silver alloy coated urinary catheters

as a means of preventing a hospital acquired catheter related UTI. The results of their model indicated that in England a 14.6% reduction in UTIs in catheterised medical patients and a 11.4% reduction in surgical patients would cover the cost of this intervention and any further reductions would result in net benefits.

3.6.3 Estimates of cost savings resulting from not carrying out 'prevention' activities which have little or no positive effect

A number of studies have looked at the appropriateness of allocation of resources to infection control practices considered to have little or no positive preventative effect. For example, Lawrence *et al.*[216] assessed the costs of routine pre-operative urine testing and subsequent treatment of asymptomatic bacteriuria in patients admitted for elective non-prosthetic knee surgery. The results indicated that routine screening and treatment cost $1.5 million per SWI prevented.

Daschner (1984) provides a summary account of a number of changes that were made to infection control policy and practice in a hospital in Germany and the estimated cost savings.[217] The aim was to move to more cost effective practise and away from infection control 'rituals' with little or no proven efficacy. For example, in the absence of an epidemic, routine environmental culturing and screening of staff for *staphylococci* was discontinued as was twice daily meatal care with PVP-iodine, changing of intravenous infusion sets every 24 hours and the use of in-line filters as a means of reducing urinary tract and bloodstream infections. These other changes were made in response to research findings. The estimated cost savings to the hospital sector as a result of these and other changes in practice over a six year period between 1977 and 1982 was 5,522,471 DM.

3.7 Conclusion

The economic evaluation of HAI presents a number of methodological difficulties. To date studies have tended to focus on the assessment of the

burden of HAI and relatively few have assessed the costs and benefits of investment in infection control activities. Studies that have assessed the economic burden of HAIs vary in scope and in terms of the methods used. However, despite these differences it is evident that the burden imposed is substantial. It is also evident that the economic burden varies with type of infection and admission specialty.

Evidence from a variety of sources indicates that whilst not all infections can be prevented some can, and studies that have directly assessed the costs and benefits of infection control activities, and the results of economic modelling exercises indicate that the benefits of investment in some cases may be considerable.

Many of the studies that have assessed the burden of HAI and the benefits of prevention have been conducted in countries other than England. Whilst the overall message that HAIs utilise considerable levels of health sector resource and impose a burden on the primary health sector, patients and carers is likely to be transferable to HAIs occurring in patients admitted to hospitals in England, the magnitude of resource use may vary. Similarly, whilst the overall message that investment in infection control activities may result in positive benefits, both in terms of health gains and the release of resources for alternative use is likely to be applicable to the situation in England, the magnitude of these benefits may also vary.

This thesis aims to provide more timely and relevant data on the costs associated with HAIs occurring in adult patients admitted to five surgical specialties common to most hospitals in England. These data may subsequently be used to demonstrate the burden these infections impose and, in conjunction with information on the cost and effectiveness of prevention activities, may be used to assist in demonstrating the benefits of prevention, and the results subsequently used to inform policy and practice.

CHAPTER 4

THE STUDY OF THE SOCIO-ECONOMIC BURDEN OF HAI

4.1 Introduction

As indicated in chapter one of this thesis, this work has developed from a study that assessed the socio-economic burden of hospital-acquired infections (HAI) occurring in adult, non-day case patients admitted to selected medical and surgical specialties of a district general hospital (DGH) in England.[2] This thesis is concerned with the incidence of HAI occurring in a sub-set of patients admitted to the surgical specialties, and the costs incurred by the hospital sector during the hospitalised phase. The methods employed in the socio-economic burden of HAI study have been reported in detail elsewhere.[2] However, since the methods employed form part of this thesis an overview of the study is provided in this chapter. The aims and objectives of the study are presented, followed by an overview of the research methods employed. Special attention is given to methods of relevance to this thesis.

The chapter limits itself to work undertaken as part of the socio-economic burden of HAI study. Details of how a subset of data relevant to this thesis was selected, the statistical analysis undertaken for the purpose of the thesis and management issues relevant to the thesis alone are presented in the following chapter (Chapter 5). A summary of the main results of the Socio-economic Burden of HAI study can be found in the study's Executive Summary, at the back of this thesis. A copy of a peer-reviewed paper, which presents the main results of the in-patient analysis, can also be found at the back of this thesis.[8]

4.2 Aims and objectives of the socio-economic burden of HAI study

4.2.1 Aim

The socio-economic burden of HAI study aimed to assess the burden of HAI in terms of the costs to the public sector, patients, their families and society as a whole.

4.2.2 Objectives

The specific objectives were:

I) To determine the overall burden of HAI in terms of:

   a) the cost to the secondary and primary health care sectors and community care services;

   b) the impact on the health status of patients;

   c) the costs to patients and their families, and to the economy.

II To establish the relative costs of different types of HAI.

III To determine the type of patients that incur the highest costs for specific infections.

IV To use the data obtained to construct models to predict the effects of HAI on the cost categories described above.

4.3 Overview of study design

The socio-economic burden of HAI study was designed to assess the impact of HAI on the secondary and primary health care sectors, community care services, informal carers and patients themselves. Adult, non-day case patients were recruited from selected wards of a DGH and daily profiles of the resources used by patients with and without a HAI were obtained. Those patients who

presented with a HAI during their in-patient stay and a sample of patients who did not, were followed up after discharge from hospital, using a structured questionnaire. This questionnaire aimed to alert the project team to possible infections experienced after discharge from hospital and provided information on care received from health and community care services, family and friends. It also provided information on costs incurred by patients and health status post-discharge. More detailed information about care received from health care services post-discharge was subsequently obtained from the patients' health care records. Estimates of the cost of the resources used were made. Statistical data analysis was subsequently conducted to determine the extent to which observed variations in the level of resources used, and the costs incurred, could be explained by the presence of a HAI. Ethical committee approval was obtained from the study hospital's Ethical Review Committee prior to both the pilot study and main study in September 1993 and March 1994 respectively.

4.4 Study site

Resources were available to explore the impact of HAIs occurring in patients admitted to selected specialties at one site. To enhance the applicability of the results to other health care settings in the UK, tertiary referral centres were excluded in favour of a DGH. Other selection criteria included similar service provision to other DGHs and easy access to the two institutions involved in the research: the Public Health Laboratory Service and the London School of Hygiene and Tropical Medicine.

The study hospital selected was part of an NHS Trust providing general acute, selected regional tertiary specialist and primary care services. It was the Trust's largest single provider of acute health care. At the time recruitment and data collection for the main study commenced (April 1994), the study hospital, which served a population of 260,000, had 579 beds, and an out-patient and an accident and emergency department. The in–patient caseload for 1994/95 was

39,898, of which 9,298 were elective cases, 20,358 emergency cases and 10242 day cases.

The budget for 1994/95 was £67 million. The aggregate resources employed by the Trust were organised into 32 directorates: 15 clinical directorates; 7 support directorates and 10 overhead directorates. Each directorate was responsible for its own budgets and was managed as quasi-independent firm producing a pre-defined range of intermediate goods and services. Of the total resources employed by the Trust, 48% were managed by the clinical directorates, 18% by the support directorates and 34% by the overhead directorates.

A retrospective assessment of how representative the study hospital was of others in England was undertaken in terms of the number of bed days produced, number of staff employed, the average cost per bed day, the average length of stay and the expected length of stay given the case mix of patients. Data on the number of bed days produced, number of staff employed and average cost per bed day at the study hospital and for hospitals throughout England were retrieved from the Chartered Institute of Public Finance Accountants/Healthcare Financial Managers database.[218] The study hospital values for these three variables were found to lie within the interquartile range of the distributions. The Health Services Indicators database[219] provided information on the average length of stay, and expected length of stay given the case mix of patients for some of the specialties involved in this study, at both the study site and at other hospitals throughout England. The study hospital values for these variables fell within the interquartile range of the distributions. These findings suggest that for the variables considered, the study hospital was not atypical of other hospitals throughout England.

4.4.1 Infection control arrangements at the study hospital

Infection control prevention and control policies and procedures operate at many different levels within any health care setting. This section describes the `formal' infection control arrangements present at the study site.

The Infection Control Team (ICT) consisted of two Infection Control Nurses (ICNs) and a microbiologist who designated approximately three hours to infection control matters per week. The infection control team covered 579 acute sector beds and a further 60 non acute beds at two other hospitals. This is equivalent to one ICN per 289 acute beds and 30 non acute beds. This ratio of ICNs to number of beds compared favourably with the national average at the time of one ICN per 477 acute and 376 non acute beds in 1995.[220]

The responsibilities of the ICT were similar to those set out in the document entitled `Hospital Infection Control: Guidance on the control of infection in hospitals' issued by the Department of Health in 1995.[9] The ICT routinely carried out 'alert' organism and condition surveillance, and when time allowed, targeted surveillance. The ICT reported to the Chief Executive and to the Hospital Infection Control Committee(HICC).

The HICC consisted of the ICT, a Consultant in Communicable Disease Control, the Director of Nursing Practice (representing the Chief Executive), a surgeon, another consultant and an occupational health physician. The HICC responsibilities were similar to those set out in the above mentioned document. Link nurses were not present in the hospital at the time the data were collected but have since been established.

4.5 Sample Size

The primary aim of the Socio-economic Burden of HAI study design was to compare the level of resources used by infected patients (and the associated costs) with those used by uninfected, but otherwise similar patients. A large component of resource use depends on length of stay (LOS). Since relevant

data on resource use were not readily available, the sample size calculations were based on a planned analysis of LOS comparing the mean values in patients with and without an HAI and using the difference between the means as an estimate of the true effect of HAI. The aim was not to test if there was a difference, but to derive adequate estimates of the magnitude of the effect. In order to do this there needed to be enough individuals in both the infected and uninfected groups so that, despite the large variation in individual LOS values, the confidence interval on the difference between the means would be acceptably narrow. The size of the smaller group primarily determines the precision of an estimate obtained as the difference between two group means. Since it was known that those infected would be only a small proportion of those in the cohort of admissions recruited into the study, it was clear that they would be the smaller group. The number recruited therefore had to be of sufficient size to ensure a large enough group of infected patients.

In order to derive sample size estimates information on the variability of LOS in both uninfected and infected patients was required. This information was obtained from a study by Coello *et al* (1993)[14] where LOS differences had been combined to calculate the standard error of the difference between mean LOS in infected and uninfected patients from three separate specialties (gynaecology, orthopaedics and general surgery and urology combined). It was assumed that the estimate required was the difference between the mean stay given a HAI and the mean stay for similar patients without a HAI. The precision of such an estimate is measured by its standard error, usually as a percentage of the value of the estimate. As indicated above a small case control study[14] provided data on the LOS differences between those with and without a HAI in three different specialties The standard errors of the LOS differences can be expressed in terms of the number of cases required, assuming at least an equal number in the non-HAI group.

It was assumed that a 10% precision would be adequate (i.e. that the standard error should be less than or equal to 10% of the estimate) and that stratified analysis would increase precision to some extent. On this basis it appeared that about 400 cases would be sufficient. Consequently if around 6% of admissions acquire one or more HAIs, 6800 admissions would be required to produce sufficient cases.

At an early stage in the socio-economic burden of HAI study it became apparent that given the resources available for data collection, it would not be feasible to recruit a sample of more than about 4700 patients. Assuming a HAI incidence rate of 6%, this sample size would yield about 282 cases of HAI. It was calculated that this reduction in the size of the smaller comparison group would reduce the precision of the analysis, defined as above, by approximately 4% so the standard error of the difference in the mean LOSs increased to 14% of the observed difference. It was concluded that this would still be sufficient to provide adequately precise results. In the event a smaller sample was recruited but a higher incidence rate was observed: 3980 patients were recruited, of which 7.8% (309 patients) acquired and presented with an HAI in hospital. At the end of the study the observed difference in mean LOS was actually found to be 13.8 days with a standard error of 1.3 or 9.4% of the difference and as such the attained precision with the reduced sample size was better than originally planned.

4.6 Subjects

The focus of the study was the socio-economic burden of HAIs occurring in adult in-patients admitted to specialties common to most hospitals. Adult patients (over 18 years of age) who had an in-patient stay of 30 hours or more, and who were admitted to the following specialties were therefore eligible for recruitment into the study: general surgery, general medicine, urology, gynaecology, orthopaedics, ear, nose and throat, elderly care and, if they had undergone a caesarean section, obstetrics. Nationally, adult, non-day case patients admitted to these specialties at other NHS hospitals in England

accounted for 70% of all adult non-day case admissions in 1994/5.[221] Resource constraints prohibited the recruitment of all patients admitted to these specialties. The study was therefore limited to patients admitted to the selected specialties on designated wards. Details of the number of wards involved in the study can be found in Appendix 4

4.7 Recruitment

Recruitment commenced in April 1994 and continued until May 1995. The informed written consent of eligible patients was obtained by one of six research assistants, all of whom were experienced Registered Nurses. The research assistants were responsible for recruitment and data collection on specific study wards. Details of the wards each research assistant was responsible for can be found in Appendix 4.

The recruitment process involved the following. The aims and objectives of the study, together with details of the information required, the data sources to be accessed and the extent of the patient's active involvement in the study were explained. It was stressed that any information obtained would be kept strictly confidential. Patients were then given an opportunity to ask questions and an information sheet about the study was given to the patient to read in their own time. After a suitable period of time the research assistant returned and answered any further questions the patient might have. If the patient agreed to participate their written consent was obtained. Finally, the research assistants informed participating patients that if they had any further questions they could either ask them when they visited the ward each day, or contact them or the project co-ordinator by phone. The information sheet included the name and telephone number of the research assistant who recruited them into the study and the project co-ordinator's contact details. These numbers were also included on posters displayed on the ward which outlined the aims and objectives of the study, the project information book kept at the nurses station on each ward, and in the letter sent to patients followed up post-discharge.

As far as possible patients were recruited into the study on the day of admission to hospital. If on admission to hospital a patient was too ill to give consent, demographic and clinical data were collected, but not included in the study until the patient was able to give consent. Any data collected on patients who subsequently did not wish to participate in the study were destroyed.

Where a patient's condition precluded the research assistant obtaining their consent at any time during the hospital stay, the consent of a close relative was sought.

Every effort was made to ensure that patients who declined participation in the study felt comfortable with their decision. It was emphasised that their non-participation would not affect their treatment in any way. The sex, age group and admission specialty of patients who declined participation were recorded, enabling the representativeness of the sample to be checked.

Time constraints prohibited the recruitment of all eligible patients. Although recruitment itself did not take up a lot of time, the collection of detailed data on resource use throughout the study-participants' stay did. The research assistants were instructed to give priority to the collection of full data sets on all study participants rather than recruiting all eligible patients.

Selection bias was avoided through guidelines, training, supervision and on going monitoring of the recruitment process. Information on the reason for non-recruitment was recorded together with the sex, age group and admission specialty of eligible patients enabling the representativeness of the sample to be checked.

Examples of the data collection form used to record these data, the patient information sheet and patient and relative consent forms are given in Appendix 5. No attempt was made to recruit patients during periods of annual leave and baseline data were not recorded on these patients.

4.8 Data collected

The following data were collected: baseline data relating to the patient population, data on the presence or absence of HAIs presenting during the in-patient and post-discharge phase; information on health sector and community service resource use; the cost of resources used; costs incurred by the patient themselves and their family and friends and information on the impact of HAI on the health status of patients (Table 4.1).

This thesis explores the economic impact that HAIs occurring in surgical patients have on the secondary health care sector as a result of additional in-patient care. As such the following categories of data are relevant to this work: baseline data relating to the patient population, data on the presence or absence of HAIs presenting during the in-patient phase; information on health sector resources use (secondary sector only) and the cost of resources used

The following sections provide details of the data variables of relevance to this thesis, the data sources used, and an overview of the methods developed to derive appropriate cost estimates of the resources used. Further details of the methods used to derived cost estimates for resources used can be found in the detailed account provided in Part II of the report of this study.[2]

Table 4.1: An overview of the data collected

Categories of information	Examples of information sought
Patient characteristics:	Age, sex, reason for admission, diagnosis, co-morbidities, household size, social class and socio - economic group Care received from formal and informal carers prior to admission.
Hospital acquired infection data: HAIs presenting during the hospital stay Infections presenting post-discharge	Site, date of onset and, if known, pathogen. Site and, if data are available, date of onset and pathogen.
Health- sector resource use and costs: Secondary sector Primary sector Community care services	 Investigations, care and treatment received Investigations, care and treatment received Care received
Costs to the patient and their family and friends: Patient Family and friends	 Expenses incurred by patients. Time of resuming normal daily activities Time of return to paid employment Care received from family and friends.
Impact of HAIs on health status:	Effect of HAI on general health status.

4.8.1 Data on patient characteristics

Data on patient characteristics included age, sex, reason for admission, primary diagnosis and co-morbidities both on admission to hospital and discharge from hospital, route of admission (e.g. elective via pre-admission clinic, elective direct to the ward or emergency via the accident and emergency department), the specialty of the admitting consultant, dates of admission and discharge, and discharge destination. This information was obtained from the medical and nursing notes.

Information on the patient's current or most recent occupation, employment status prior to admission to hospital (e.g. unemployed, self employed, employed), and household size and composition was obtained from either the patient, a relative or the medical/nursing records. If obtained from the medical or nursing notes, as far as possible it was verified with the patient and/or relative or friend. Based on the information provided (current or most recent occupation and employment status prior to admission to hospital) patients were categorised into social class and socio-economic groups according to the OPCS classification system.[222]

Information on the care received prior to admission from the formal sector and family and friends was also obtained. Formal sector care included district nursing services, meals on wheels and home help services. Care from family and friends included assistance with daily activities of living such as washing, dressing and cooking and regular visits made by family and friends to check that the patient was managing. This information was obtained from the patients, their relatives or friends, or the medical or nursing notes. If obtained from the medical or nursing notes, as far as possible it was verified with the patient and/or relative or friend.

4.8.2 Data on HAIs presenting during the hospital phase

HAIs presenting during the in-patient phase were identified using the reference method of surveillance described in the Public Health Laboratory Service (PHLS) report `A Study of Surveillance Methods for Detecting Hospital Infections.'[77] This method aims to identify all patients with a HAI. It involves liaison with ward personnel and consulting all relevant data sources, such as laboratory reports and nursing and medical records, to identify signs and symptoms associated with HAIs. If these met the definitions of infections used in this study a HAI was recorded, together with the site of infection, date of onset and, if known, the pathogen(s) involved. The definitions used in this study were those developed as part of the aforementioned PHLS report.[77] Minor changes were made to the text to aid interpretation and use (Appendix 6).

4.8.3 Data on health sector resource use during the hospital phase

Data on the resources used during each patient's stay in hospital were collected. This included all investigations carried out (for example X-rays, laboratory tests, endoscopies and cardiac tests); procedures performed (for example operations, insertion of intra-vascular catheters, insertion of urinary catheters); care administered (for example care administered by nurses, physiotherapists, occupational therapists) and drugs and intravenous infusions administered. This information was obtained from a variety of data sources including medical and nursing notes, the notes of other relevant health care professionals, laboratory print outs and drug prescription charts. Information was also obtained about care organised for dependants whilst the patient was in hospital, for example respite care. This information was obtained from the patient or a relative or friend.

4.9 Methods used to derive cost estimates of the resources used

A detailed approach was taken to the estimation of the cost of resources used. This section provides an overview of the methods used to derive estimates of the cost of hospital resources used during the patient's in-patient stay. A detailed account is reported elsewhere, together with an account of the methods used to derive estimates of the costs of other resources used.[2]

4.9.1 Methods used to derive cost estimates of hospital resources used during the in-patient phase

As indicated in section 4.3 information on the resources used by patients during their admission was collected for each patient regardless of whether they had an infection. These resources may be broadly classified into two groups those associated with occupying a hospital bed (i.e. the cost of maintaining a hospital bed) and those relating to specific care and treatment administered to individual patients.

Estimates of the costs of occupying a hospital bed were derived as follows. Data on the costs of the overhead directorates were obtained from the Trust. Overhead directorates included the following: finance, estates, hotel services, personnel, planning, Trust management, technical services, education and training and the reserves directorate.

An allocation model was subsequently developed whereby specialty specific estimates of the average daily cost of occupying a bed were derived. The model took into account the proportion of individual overhead directorate costs used by each specialty and the proportion of individual overhead directorates costs used by the other overhead directorates. A detailed account of the allocation model and the assumptions that informed it can be found elsewhere.[2] The resulting specialty specific estimate of the cost per bed day was subsequently multiplied by the patient's length of hospital stay to derive individual patient estimates of the cost of occupying a bed.

Costs associated with care and treatment administered included the cost of medical time, nursing time, the time of other health care professionals such as physiotherapists, and the cost of diagnostic investigations, procedures carried out and consumables used.

Cost of medical care: The amount of medical care patients receive varies with the patient. In order to gain an accurate assessment of the cost of medical care received, it would be necessary to record and cost all contacts that patients had with members of the medical profession over the course of their hospital admission, and determine the time medical staff spent planning and organising care for individual patients. Unfortunately, resource constraints prohibited such an approach. The average daily cost of medical care was derived for each specialty and allocated to patients in the study in accordance with the length of hospital stay.

Cost of nursing care: Nursing costs were allocated to patients based on the amount of nursing care patients received each day. The method used to allocate nursing care costs was based on a system developed and extensively validated in Australia. It was subsequently introduced to the Hammersmith Hospital, London in 1988 and internally validated. The system involves allocating patients to one of seven care groups determined by the amount of care received within a nursing shift. The seven care groups represent a spectrum of care extending from patients that require minimal care (care group one) to those who require extensive nursing care (care group seven). An appropriate cost is then calculated for each care group based on the amount of available nursing time patients falling into each care group are thought to consume. The cost of nursing care for each patient can then be calculated by summing the nursing care costs for each nursing shift over the whole hospital stay.

Cost of contacts with professionals allied to medicine: Average costs of consultations with chiropodists, speech therapists, dieticians, occupational therapists and physiotherapists were derived from cost and activity data supplied by the study hospital and allocated in accordance with the number of contacts supplied to individual patients

Costs of investigations: The cost of radiological investigations were derived by applying Korner weights to cost and activity data supplied by the study hospital. The average unit costs of microbiology, chemistry, haematology and histopathology tests were derived from cost and activity data supplied by the trust.

Cost of surgery: The costs associated with surgery were derived by first calculating a cost per session for each specialty from which a cost per minute of theatre time for each specialty could be derived. The derived costs included the cost of running the theatre. This included the cost of nursing staff, technicians, management and administrative staff; the cost of consumables associated with

the provision of surgical interventions, including pharmacy inputs, medical gases, drapes, surgical equipment and dressings; and finally indirect and capital inputs. The cost per session did not include the cost of a surgeon's time which was included in the costs of medical time allocated separately to each patient on a daily basis

The second stage involved calculating the cost per procedure. This was achieved by applying the specialty specific cost estimates derived above (cost per minute of theatre time for each specialty) to data on the average time associated with procedures classified according to level of complexity (i.e. minor; intermediate and major and a number of intermediate levels). This information was supplied by the study hospital.

The third and final stage involved classifying the operative procedures undergone by individual patients by level of complexity using the classification system described above which is used by BUPA (1993),[223] and subsequently applying the appropriate cost estimate derived as described above. Further details about the methods used, including how sub-procedures were costed, are reported elsewhere.[2]

Cost of pharmaceuticals: Estimates of the cost of pharmaceuticals supplied were derived by combining the price of the drugs (determined as a result of negotiation between the pharmacy at the study hospital and the pharmaceutical industry), with the costs of any consumables associated with the delivery of the drug. For example, the cost of an intra-muscular antibiotic would include the cost of the drug, a syringe, the fluid with which the drug is mixed, and two needles (one used to mix the drug and one to administer the drug).

The costs of consumables supplied to patients: The cost of consumables such as intravenous catheters, wound drains, and urinary catheters were derived from the NHS supplies catalogue (1994).[224] The combination of resources used

to supply a product was based on information provided by an F-grade nurses familiar with clinical practice at the study hospital.

Once these unit costs were available they were multiplied by the data collected on resources used by the patients. This allowed the development of cost profiles for all study participants. These profiles provided information on the total cost of resources and the contribution of specific components of cost to the total costs incurred.

4.10 Data Management

Data were recorded on data collection forms designed using optical scanning software designed by Formic Ltd (see Appendix 7 for examples). The data were then scanned onto the scanning software database and exported in either Dbase or SPSS format for analysis at the Central Public Health Laboratory and London School of Hygiene and Tropical Medicine. This method of data entry has been shown to be 99.9% accurate in test-re-test studies.[225] Prior to analysing the data a number of data checks were made to eliminate any substantial recording errors. The data cleaning process included checking that all surveys had been scanned completely and a number of range, categorical and logical checks. For example, checks were made that the date of discharge was after the admission date; that only females were recorded as having been admitted to the gynaecology and obstetric wards and specialties, that the ages recorded fell within an acceptable range (18-100), and the ICD9 diagnosis codes were valid and appropriate given the patient's sex and admission specialty.

At all times patient information was handled in ways that maintained patient confidentiality. Patients participating in the study were identified by a unique study number. This number was the only form of patient identification stored on the database. Personal details, such as the patient's name, address and hospital number, were stored on a separate computer whose use was restricted to named individuals. Those responsible for collecting and handling data

received appropriate training and were asked to sign a document outlining the standards for data handing, and record keeping. A copy of this document is at Appendix 2

4.11 Data analysis

4.11.1 Checking for recruitment/selection bias

The age, sex, admission type and admission specialty distributions of patients recruited into the study were compared to the distributions that would have been present if all eligible patients were recruited.

4.11.2 Incidence of HAIs presenting during the in-patient period

The number of patients with one or more hospital-acquired infections presenting during the in-patient period was expressed as a percentage of the number of patients discharged and 95% confidence intervals derived. Site and specialty specific estimates were also derived.

4.11.3 Incidence of HAIs presenting post-discharge

Estimates of the proportion of patients reporting symptoms and treatment which met the study criteria for infections presenting post-discharge were derived for four groups of patients: patients who did not have an HAI identified either during the in-patient or post-discharge phase; patients who had no in-patient HAI, but had evidence of a possible infection post-discharge; patients who had an HAI identified during the in-patient phase but no evidence of an infection post-discharge and finally patients who had an HAI identified during the in-patient phase and had evidence of a possible infection post-discharge.

4.11.4 Attribution of costs to HAIs

4.11.4.1 In-patient analysis

Attributing resource use and costs to the presence of an infection presents a number of difficulties. Factors other than infection may have an impact on resource use. In this study linear regression modelling techniques were used to control for a range of factors that could potentially influence the level of

resource use: age, sex, diagnosis, number of co-morbidities, admission specialty, and admission type. Since the cost and length of hospital stay distributions included a few very high values they were skewed to the right. For this reason the analysis was performed assuming that the underlying distribution was Gamma in form (this distribution, very similar to the log-Normal, is appropriate for skewed data).[226] Estimates of the impact of one or more hospital-acquired infections, and of specific types of infection, adjusted for the effects of confounding variables were derived from this modelling process.

During the analysis the effects of social class, nursing dependency (defined as the average level of nursing care required from admission to the time the HAI was identified) and disease stage were also investigated. This last variable is a measure of severity of illness, derived from information on the patients' age, sex, diagnosis, co-morbidities, operation codes, admission type, length of in-patient stay and discharge destination. Previously validated algorithms[227] were used to allocate patients to one of three disease stage groups (low, medium and high) depending on the severity of their illness using software developed by CHKS Ltd. The inclusion of these additional variables was found to have very little effect on the estimated impact of HAI on hospital sector costs once the other explanatory variables had been taken into account.

4.11.4.2 Post-discharge analysis

The primary outcome measures for the post-discharge analysis included the number and cost of general practitioner, district nurse, hospital doctor, health visitor and community midwife visits, and the costs to patients and their informal carers. As with the in-patient analysis, the variables had skewed distributions. Ideally the distribution used in the in-patient analysis (Gamma distribution) would have been used in the post-discharge analysis. However, the data had many zeros for these outcomes. Consequently the Gamma distribution was considered inappropriate and a log normal distribution was used for the regression modelling.

4.11.5 *Impact of HAI on health status*

This aspect of the analysis was limited to the impact of HAI on health status as measured by the responses given to the general health status questionnaire, the Short-form 36 (SF-36), administered within the post-discharge questionnaire. Mean scores for the eight dimensions of health covered by the SF-36, were derived using the standard SF-36 scoring algorithms[228] and mental and physical summary scores subsequently derived, again using the standard scoring systems.[229] These were compared to the norms derived in the Oxford Healthy Lifestyle Study[230]using the two sample unpaired t-test. Mean scores for each dimension of health and for the two summary measures were then determined for patients within each of the four HAI groups and the impact of HAI on these measures determined. Regression analysis as described above was used to control for factors other than the presence of an infection that might influence the scores obtained.

4.11.6 *Deriving national estimates of the number of patients who acquired one or more HAIs*

National estimates of the number of adult patients who acquired one or more infections in hospital, which presented during the in-patient stay were derived by applying the observed in-patient incidence rate and 95% confidence interval to data on the number of adult patients (≥18), excluding day cases, admitted to similar specialties, in NHS provider units throughout England in 1994/5. The same approach was used to derive specialty specific estimates of the number of patients acquiring one or more infections and estimates of the number of patients acquiring specific types of infection.

4.11.7 *Deriving national estimates of the cost of HAIs to the hospital sector*

Estimates of the burden these infections imposed on the hospital sector were derived from data on the observed incidence of hospital-acquired infections presenting during the in-patient period; the estimated ratio of the hospital costs incurred by infected compared to uninfected patients obtained from the linear

modelling analysis; the mean hospital costs incurred by uninfected patients; and data on the number of adult admissions. If N is the number of patients admitted nationally, C the baseline cost of treating uninfected patients, *i* the estimated incidence and *r* the estimated ratio of costs incurred by infected compared to uninfected patients, then N*i* *C(r-1)* provides an estimate of the national burden.

The variance of this estimate was derived from the standard deviations of the estimates of the incidence and ratio of costs, sd*i* and sd*r* respectively, as follow: $N^2 C^2 [i^2 sdr^2 + (r\text{-}1)^2 sdi^2]$

This estimated variance was subsequently used to obtain 95% confidence intervals for the estimates of the national burden of infection, it being assumed that the sampling error in such an estimate would be approximately normal. Estimates of the number of additional days patients remained in hospital and site and specialty specific estimates of the burden imposed were made using the same approach.

4.12 Project Management

The socio-economic burden of HAI study was a joint venture by the Central Public Health Laboratory and the London School of Hygiene and Tropical Medicine. The project team were responsible for the organisation and conduct of the study. Over the course of the study it comprised of the following members: a project co-ordinator, research economist, six research assistants, a statistician, a project secretary and a part-time administrative assistant.

The project team was advised by a multidisciplinary steering group consisting of experts in infection control, microbiology, epidemiology and economics. The project steering group met as and when was required. The project steering group and team were advised by a multi-disciplinary Advisory Committee comprising DH representatives, and experts in infection control, microbiology, economics and community nursing. Appendix 8 provides details of the members of the project team, steering group and advisory committee.

4.13 Project Timetable

The socio-economic burden of HAI study was commissioned by the DH to the Central Public Health Laboratory and London School of Hygiene and Tropical Medicine in October 1992 and a project co-ordinator (Rosalind Plowman) appointed in July 1993. The study comprised of four key phases listed below.

Phase 1: This was conducted over a period of nine months from July 1993 to March 1994 and involved a literature review, the development and piloting of the study tools and research methods, and their subsequent modification in the light of the findings of the pilot study.

Phase 2: This was conducted over a period of 16 months from April 1994 to July 1995 and constituted the main data collection period.

Phase 3: This was conducted over a period of 13 months from August 1995 to September 1996 and involved the validation, analysis and interpretation of the data set for the purposes of the costs study and final Department of Health Report.

Phase 4: This involved the preparation of the final cost study report and its submission to the Department of Health for internal and external review and subsequent modification. This was conducted over prolonged period of time. The report was submitted to the Department of Health in August 1997 and distributed for internal and external review. A full set of reviewer's comments was received in November 1997. A formal response was submitted to the Department of Health in February 1998 following which there was a period of discussion and debate. Further editing work and additional analysis was undertaken. Amendments to the original text together with the results the additional analysis requested were submitted to the Department of Health in September 1998 and the report accepted for publication in September 1999, and finally released in January 2000

4.14 Conclusion

This chapter has provided an account of the methods used in the socio-economic burden of HAI study. The methods used in the socio-economic burden of HAI study, in particular those that relate to the impact of HAI on hospital resource use and costs, are common to this thesis. The following chapter builds on the information presented in this chapter. Details about how data on patients of interest to this thesis were selected from the socio-economic burden of HAI data set are presented, together with an account of the analysis undertaken.

CHAPTER 5
METHODS

5.1 Introduction

The preceding chapter has described in some detail the study to which this thesis is linked. As stated in the preceding chapter the methods employed in the socio-economic burden of HAI study are common to this thesis. In this chapter the aims and objectives of this thesis will be presented and discussed, followed by a detailed account of the methods which are particular to this work. The chapter describes how a subset of data was selected from the data set collected as part of the socio-economic burden of HAI study, and the statistical analysis undertaken. Details regarding data and project management are also presented.

5.2 The aims and objectives of this thesis

5.2.1 Aim

To assess the incidence of, and independent risk factors for HAIs occurring in surgical patients admitted to a district general hospital and the impact these infections have on the secondary health care sector, and to examine how the information obtained may be used to assess the potential benefits of investment in the prevention and control of HAIs.

5.2.2 Objectives

The specific objectives were to:

1. Review the literature on the epidemiology of HAI, risk factors for HAI, and the economic evaluation of HAI.

2. Determine the incidence of HAIs occurring in adult, non-day case patients admitted to selected surgical specialties of a district general hospital.

3. Explore how the incidence of HAI varies with various patient characteristics and identify possible risk factors.

4. Determine the impact HAIs occurring in this patient group had on secondary health care sector resource use and costs.

5. Examine how information on the economic burden of HAIs may be used to assess the potential benefits of investment in the prevention and control of HAIs.

5.3 Overview of study design

As detailed in the preceding chapter, the study to which this thesis is linked was designed to assess the impact that HAIs occurring in medical and surgical adult patients had on the secondary and primary health care sector, community care services, informal carers and patients themselves. This thesis is concerned with the incidence of HAIs occurring in patients admitted to the surgical specialties and presenting during the in-patient period, risk factors for these infections and the impact these infections had on secondary health care sector resource use and costs as a result of additional in-patient care. Thus data relating to the incidence of HAI occurring in surgical patients, risk factors for these infections and the resources used during the in-patient period, collected as part of the socio-economic burden of HAI study, are of relevance to this thesis. An overview of how these data were collected, and the analysis undertaken for the purposes of this work follows.

Adult, non- day-case patients were recruited from selected wards of a district general hospital. Background demographic data were collected on all patients together with information on selected risk factors. Information on infections presenting during the hospitalised phase was obtained through surveillance using validated surveillance methods and case definitions. Data on resources used by all patients were collected resulting in daily profiles of the resources used by patients with and without a HAI. Estimates of the cost of the resources

used were made. A sub-set of data relating to patients admitted to the surgical specialties was subsequently identified and statistical data analysis conducted to determine the incidence of HAI, independent risk factors for infection, and the extent to which observed variations in the level of resources used, and the costs incurred, could be explained by the presence of a HAI. How information on the economic burden of HAIs may be used to assess the potential benefits of investment in the prevention and control of HAIs was subsequently explored.

Details regarding the study setting, how patients were selected and recruited into the study, the data variables of interest and data collection methods employed can be found in section 4.4-4.8 of Chapter 4. The following section describes how the subset of data of relevance to this thesis was selected.

5.4 Selection of surgical patients and relevant data for the purposes of the PhD thesis

This thesis is concerned with the incidence of HAIs occurring in adult patients admitted to selected surgical specialties, risk factors for these infections, and the impact these infections have on hospital resource use and costs as a result of additional in-patient care. The wider socio economic burden of HAI study included data on patients admitted to five surgical specialties: general surgery, orthopaedics, urology, gynaecology, and if they had undergone a caesarean section the obstetric specialty. This section provides details of how patients admitted to these specialties were identified and how the subset of data relevant to this work was compiled.

Patients admitted to the five specialties of interest could be identified from the underlying data set on the basis of admitting ward, specialty or consultant. It was decided to select patients on the basis that their admitting consultant was not an ENT surgeon, physician or geriatrician, but a general surgeon, gynaecologist, urologist, obstetrician or orthopaedic consultant.

Prior to selecting patients on the basis of their consultant code the validity of this approach was checked. The final data set was renamed and the admission consultant, ward, specialty and diagnosis cross-checked to assess the face validity of this information: i.e. given the consultant's speciality would you expect the documented ward and admission specialty. Unusual records were highlighted and looked at in more detail. That is reports including primary diagnosis, co-morbidities, ward transfer and consultant transfers were generated and examined. Judgements were subsequently made about the data and the data file modified as necessary. For example, if the patient's consultant was recorded as being a gynaecologist, but the ward, specialty and diagnosis indicated the patient was a urology patient, the assumption was made that this was a urology patient and the consultant code changed to indicate that this assumption had been made. Or if the consultant, specialty and diagnosis indicated that the patient was a gynaecology patient but the ward was surgical, it was assumed that there were no beds available on the gynaecology wards and no changes were made. Once this process was complete patients were selected on the basis of admitting consultant code and reports generated and checked again. Having completed this second check the data set for this work was selected, and saved as a separate data file.

Within this limited data set there were eight patients who were transfers from another ward or hospital. These patients by definition will have incomplete in-patient data sets: their data sets will relate to varying proportions of their hospital stay. Consequently these eight patients were excluded from the final data set used.

Having identified the patients, data relating to their hospital stay were obtained from the relevant survey databases, and datasets specific to the needs of this thesis were created. For example, datasets limited to surgical patients were created for information on operations undertaken, procedures performed, investigations carried out and nursing care administered. Further data checking was also carried out, including range, categorical and logical checks.

Whilst carrying out this procedure it was noted that the number of surgical patients for whom there were data on operative procedures appeared rather low. The data relating to the first operation indicated that only 1936/2469 (78.4%) patients included in the surgical data set, had evidence of a first operation having been performed. In 533 cases (21.6%) there was no evidence of a first operation having been performed. This rather surprising observation was felt to warrant further investigation. Did the data accurately reflect the procedures performed? If the data set was a valid account of procedures performed, did the level of surgery performed in the recruited sample reflect the level performed in the wider population sample? Had important information not been entered and as such was the data set incomplete?

In order to investigate these important questions the hospitals Patients Administration System (PAS) data set for the year 1994/5 was analysed to determine what proportion of the wider hospital population, admitted to the specialties included in this study, had an operative procedure. The analysis revealed that during the year 1994/5 67% of the patients admitted to the surgical, gynaecology, orthopaedic and urology specialities had an operative procedure. This was in fact lower than the percentage of patients in the study sample who had undergone an operative procedure. At face value this was an encouraging finding. Furthermore, it was noted that not all the operation codes included in the PAS data related to actual operations. Some referred to procedures such as blood transfusions and endoscopies. Despite this it was considered necessary to explore the situation further.

As far as possible the PAS records of study patients who did not have any evidence within the study database of a surgical operation having taken place were checked. Of the 533 patient records checked, data were available for 524 patients. In 148 (28.2%) cases there was evidence that an operative procedure had taken place (i.e. an OPCS code included in the PAS database). However, in 43 cases the operation codes were for procedures, which in this study were not classified as an operation – e.g. blood transfusion, removal of catheter and

endoscopy. As such according to the PAS database it would appear that 105 (20%) of the 524 patients for whom no operation data were available in the study database and data was available in the PAS database, in fact had one or more operations. As such, the operation codes for these 105 patients were entered into a newly created data variable within the reduced operations dataset. The project economist subsequently derived cost estimates for all 105 cases and the information was entered onto the database within a newly created variable denoting revised operation costs, and it was accepted that the remaining 419 patients did not have an operation. It was also accepted that the 15 patients for whom there was no evidence of surgery having taken place in the study database and no evidence of admission in the PAS database, did not have surgery. As such an estimated 2041 (82.7%) of the 2469 patients included in this study had one or more operative procedures.

This process of checking the validity of the operation data revealed a second related problem. It was noted that of the 1936 patients for whom there were data within the study database on the surgical procedure performed, cost estimates were only available for 1830 patients: 106 of the 1936 patients for whom operation data were available did not have a cost derived for the operation performed. This situation was addressed as follows. In 57 of the 106 cases for whom there was evidence within the study database of an operation having been performed but no cost estimates, costs were derived and entered onto the database. Estimates were derived using the methods developed for the underlying study, reported in detail elsewhere[2] and briefly summarised in section 4.9.1. In the remaining 49 cases there was evidence of surgery having taken place, but procedure codes had not been entered onto the database. As far as possible these codes were obtained from the PAS database and cost estimates derived. In 37 cases procedure codes were obtained from PAS and subsequently used to derive cost estimates. However, in two cases there was no evidence of an operation in the PAS database and in the remaining ten cases there was no evidence of admission to hospital in the PAS database.

Once new operation costs had been derived and entered the final stage was to compute a new total cost estimate substituting the newly derived operation cost data for that originally used.

Having created a number of datasets limited to surgical patients, a number of new variables summarising specific aspects of resource use were subsequently computed from the raw data. For example, a variable was created to denote whether patients had received antibiotics prior to the onset of infection. In order to create this variable, it was first necessary to create an antibiotic data set from the many data collection forms that included antibiotic drugs. Antibiotic drug use had been recorded on six different types of data collection forms. These forms had been designed to collect data on oral drugs, intravenous and intra-muscular drugs, intravenous infusions, operations performed, and drugs that had not been listed elsewhere. The latter included two different data collection forms one with space for recording data on up to six drugs not listed elsewhere and the other space for recording up to 12 drugs that had not been specifically listed elsewhere.

With the exception of the last three forms, the data collection forms related to two-week periods. That is for each type of data collection form there was a form relating to weeks 1-2, another for weeks 3-4 and so on. In order to create one antibiotic database, data collection forms relating to the different two-week periods were merged. These merged datasets, relating to different types of data collection forms, were then brought together into one antibiotic dataset.

Once an antibiotic database had been created it was then possible to create a new variable denoting whether the patient had received antibiotics prior to the onset of an infection, and whether the antibiotics received were administered via the oral, intravenous or intramuscular route, or by all three modes of administration.

Using a similar approach three new variables were created to denote whether patients had a urinary catheter, one or more wound drains or a naso-gastric or endotracheal tube in situ prior to the onset of infection.

5.5 Data analysis undertaken for PhD thesis

The data were analysed using SPSS 10 and STATA version 7. The data analysis included a descriptive analysis of the data set, a more detailed exploration of the incidence of HAI and possible risk factors for these infections, and estimation of the costs attributable to HAI.

5.5.1 Descriptive analysis

A descriptive analysis was undertaken. This included an exploration of the age, sex, specialty, admission type, primary diagnosis, and number of co morbidities. Where appropriate cross tabulations were developed, and tests for significance were conducted using the Chi-Square test. In order to check the representativeness of the recuited sample the age, sex, admission type and admission specialty distributions of study participants and eligible patients who either declined or were not recruited due to practical reasons, such as insufficient time, were analysed and compared. Appendix 9 provides details of how the variables listed were categorised for the purpose of the analysis.

5.5.2 Incidence of HAI and identification of risk factors

The incidence of HAI was assessed in terms of the following two definitions:

i) the number of patients with one or more HAIs expressed as percentage of the number of patients discharged
ii) the number of primary HAIs/1000 patient days at risk

For each definition a single variable analysis was conducted to assess how the incidence varied with selected patient characteristics (age, sex, admission specialty, admission type, diagnosis group, number of co-morbidities, presence of absence of diabetes mellitus, and whether the patient had an operation).

Based on definition (i) above, a multivariable logistic regression analysis was conducted to assess which factors were independently associated with risk of acquiring an infection. The significance of the effects of each variable in the analysis was assessed using likelihood ratio χ^2 tests.

The above analysis was repeated for each type of infection: urinary tract, surgical wound, chest, bloodstream, skin and infections at sites not classified elsewhere. The variables included in the risk factor analysis varied slightly with site of infection. For example, the analysis examining the incidence of UTIs included a variable denoting presence or absence of a catheter prior to the onset of infection. Further details of the variables included are presented in the relevant result sections in Chapter 7.

5.5.3 Economic impact

The analysis considered the impact of HAI on two measures of resource use: hospital costs and length of hospital stay.

5.5.3.1 Single variable analysis

Single variable analysis was conducted to assess how hospital costs and length of hospital stay (LOS) varied with infected and uninfected patients and other patient characteristics including age, sex, admission specialty, admission type, primary discharge diagnosis group, and number of co-morbidities. The mean and median hospital costs incurred and length of hospital stay were calculated together with the 25th and 75th percentiles, minimum and maximum values and the standard deviation. As the data were skewed the significance of the observed differences was assessed using the non-parametric Mann-Whitney and Kruskal-Wallis tests.

5.5.3.2 Multivariable analysis - overview

The single variable analysis indicated that both LOS and hospital costs not only varied with HAI status but also with a number of factors including age, sex, admission type, and number of co-morbidities (see Chapters 8 and 9). In order to assess the independent effect of HAI on hospitals costs and LOS multivariable regression analysis was undertaken. The aim was to assess the impact of HAI on hospital costs and LOS after controlling for other factors that might influence the magnitude of the costs incurred and a patient's LOS. With the exception of primary discharge diagnosis group the regression analysis to assess the impact of HAI on LOS and costs included all the factors included in the single variable analysis (equations 1 and 2). Primary discharge diagnosis group was excluded as the number of patients in many of the subgroups was very small.

Equation 1:

Hospital costs regressed on sex, age, admission specialty, admission type, number of co-morbidities, HAI status.

Equation 2:

Length of stay regressed on sex, age, admission specialty, admission type, number of co-morbidities, HAI status.

Further details of the explanatory variables included in this analysis can be found in Appendix 9.

5.5.3.3 Normal linear regression – no transformation of dependent variable

Multiple regression analysis is based on a number of assumptions: independence, linearity, normality, and constant variance:

1. The observations should be independent.
2. The relationship between the dependent and independent variables should be linear.
3. For each combination of values of the independent variables, the distribution of the dependent should be normal.
4. For each combination of values of the independent variables the distribution of the dependants should have a constant variance.

These conditions were not met in this data set. Both dependent variables (LOS and hospital costs) had a skewed distribution and the variance was not constant. Figure 5.1 plots the quantiles of LOS against the quantiles of the normal distribution and Figure 5.2. the quantiles of hospital costs against the quantiles of the normal distribution. If the data were normally distributed the plotted points would lie approximately on a straight line. It can be seen from figures 5.1 and 5.2 that this is not the case with respect to the LOS and cost data, indicating that both the LOS and cost data are not normally distributed.

Figure 5.1: A plot of the quantiles of LOS against the quantiles of the normal distribution

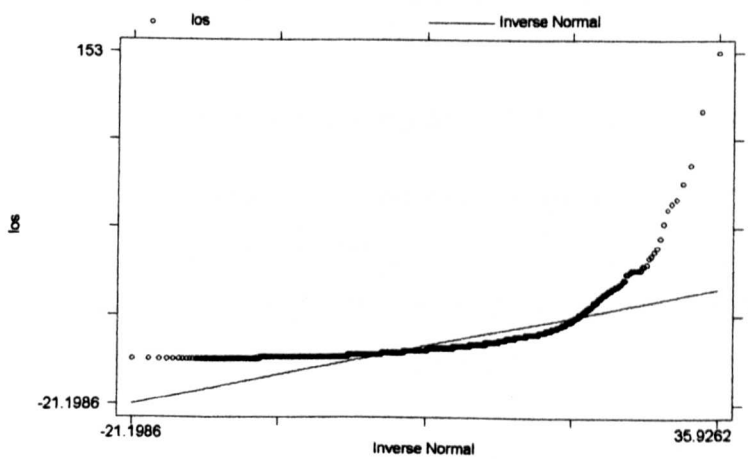
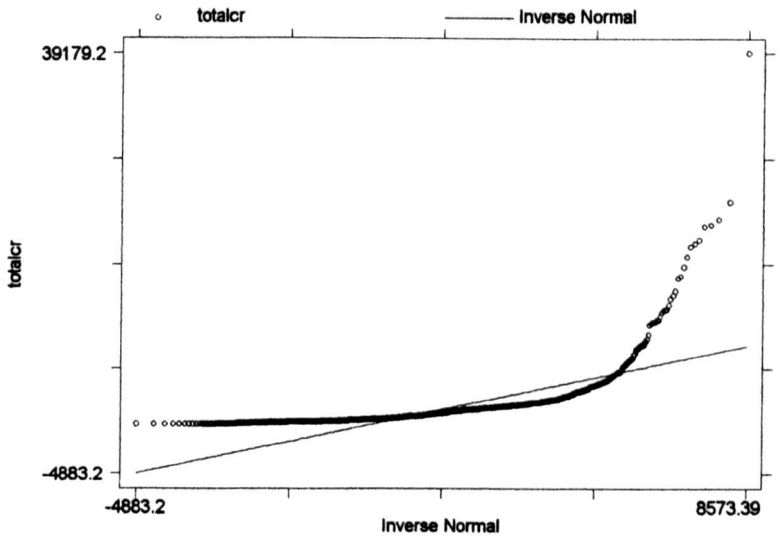


Figure 5.2: A plot of the quantiles of hospital costs against the quantiles of the normal distribution



A quantitative assessment of the deviation from Normality was made using the Shapiro Francia W' test. The results presented in Table 5.1 indicate that both the LOS and cost data were not compatible with a Normal distribution (p= 0.00001).

Table 5.1 : Shapiro- Francia W' test for normal data

Variable	Shapiro- Francia W' test for normal data				
	Obs	W'	V'	z	Prob>z
Length of stay	2469	0.56361	499.748	7.979	0.00001
Hospital costs	2469	0.50115	571.277	8.047	0.00001

5.5.3.4 Linear regression – log transformation of dependent variable

A frequently used method to deal with skewed data is to transform the data onto a log scale. Transforming the LOS and hospital costs data on to the log scale (log LOS base 10 and log Cost base 10) produced a distribution that is closer to the normal distribution (figure 5.3 and 5.4).

Figure 5.3: A plot of the quantiles of LOS transformed onto the log scale (base10) against the quantiles of the normal distribution

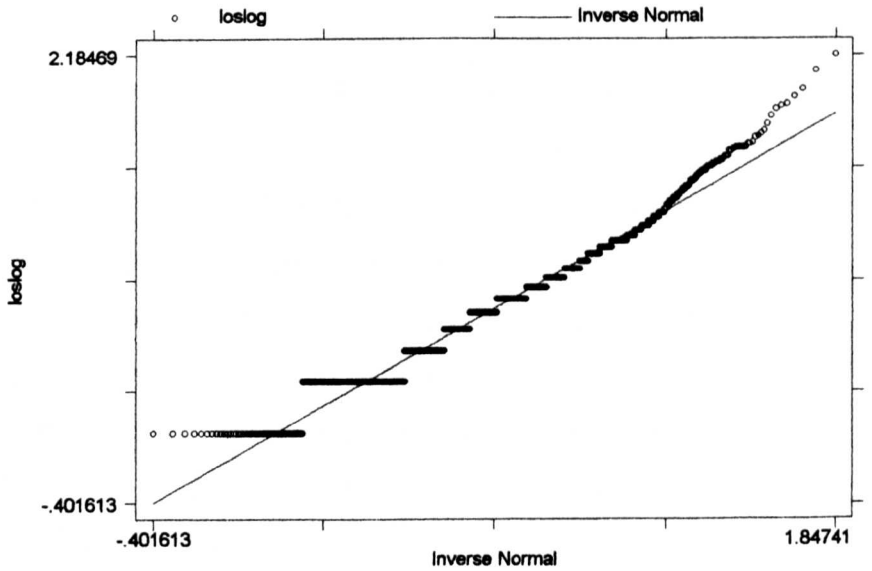
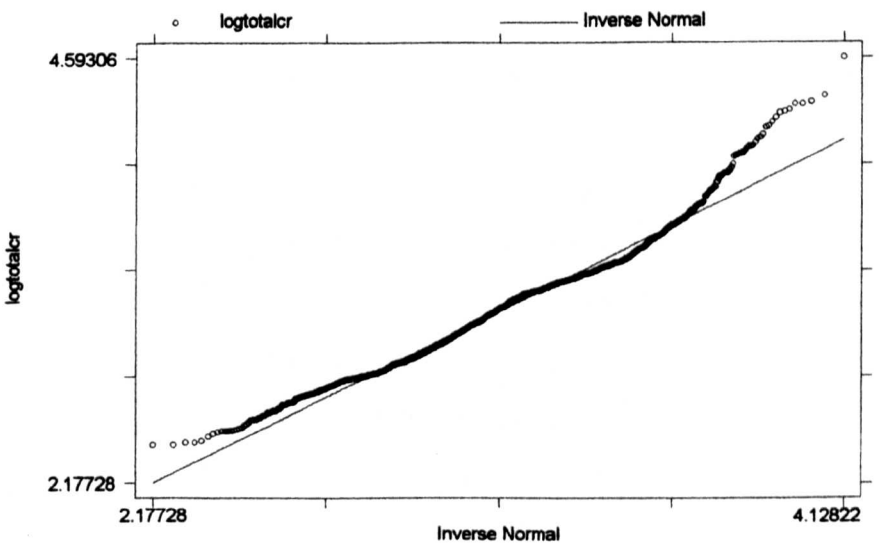


Figure 5.4: A plot of the quantiles of hospital costs transformed onto the log scale (base10) against the quantiles of the normal distribution



However, it is clear from Figures 5.3 and 5.4 that even after transformation onto the Log (base 10) scale there remains positive skewness, with this being more marked in the case of hospital costs than hospital length of stay. Transformation onto the Log 10 scale does not pull the tail of the distribution in

quite enough. The higher observed values are still higher than expected given the mean and standard deviation. A shifted transformation may have produced a distribution closer to the normal distribution, but its use would make interpretation more difficult. Furthermore, even in the absence of a shifted transformation, interpretation problems arise. The estimates and confidence intervals derived from regression models in which the dependent variable is transformed onto the log scale are measured on the log scale. To obtain a clear interpretation the estimates would need to be transformed by exponentiation (anti- logarithms) back to the original scale. This would produce estimates of the ratio of hospital costs and LOS for each level of a variable category group compared to the categories base line. Thus for the HAI variable it would produce a ratio of hospital costs incurred by infected patients compared to uninfected patients, and a ratio of hospital LOS in infected compared to uninfected patients. Difficulties arise when estimating the magnitude of these increases in terms of additional costs incurred and the number of extra days patients remain in hospital. Whilst the ratio of costs or LOS could be applied to the arithmetic mean costs or LOS of uninfected patients, it is questionable whether this is appropriate given that the ratios were derived on the log scale.

5.5.3.5 Generalised linear modelling assuming a gamma distribution

An alternative approach to dealing with the problem of LOS and hospital costs having a skewed distribution is to assume that the skewed outcome variables have a Gamma distribution, which is very similar in form to the Log/Normal distribution, and construct generalised linear models which allow estimation of the effect of HAI on LOS and costs, allowing for the effects of the other factors included in the model, utilising a maximum likelihood approach. This approach was used in this analysis.

The Gamma distribution has a decreasing coefficient of variation (standard deviation/mean) as the mean increases. To assess whether it was appropriate to assume an underlying Gamma distribution the mean LOS and mean total costs were plotted against the standard deviation for LOS and total costs

(Figures 5.5 and 5.6) and the coefficients of variation (sd/mean) plotted against the categories involved for both LOS and costs (Figures 5.8 and 5.9). Figures 5.5 and 5.6 show that the standard deviation for LOS and total costs increases with increasing mean LOS and total costs and Figures 5.7 and 5.8 show that the coefficients of variation for both LOS and total costs decrease slightly with increasing mean. As such, for the purposes of the analysis it was considered appropriate to assume an underlying Gamma distribution.

Figure 5.5: A plot of the mean length of stay against the standard deviation for length of stay

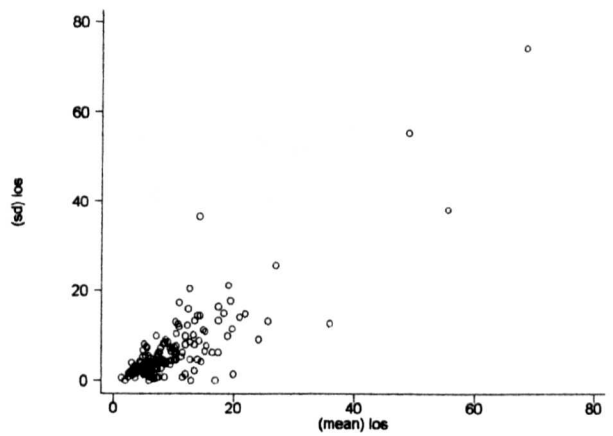


Figure 5.6 A plot of the mean hospital costs against the standard deviation for hospital costs

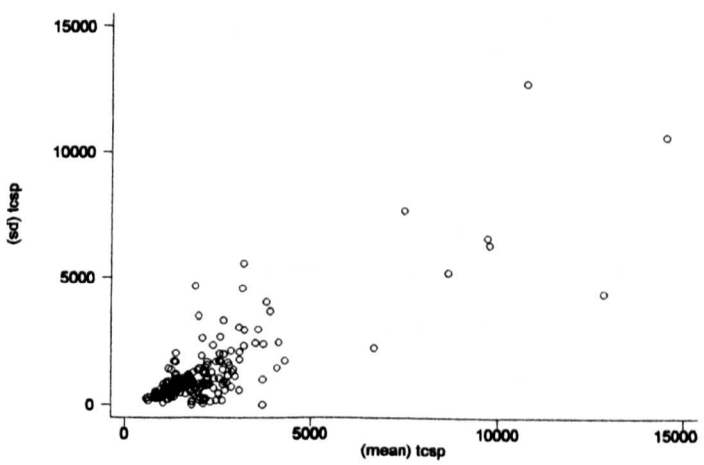


Figure 5.7: A plot of the coefficient of variation of LOS against the categories involved

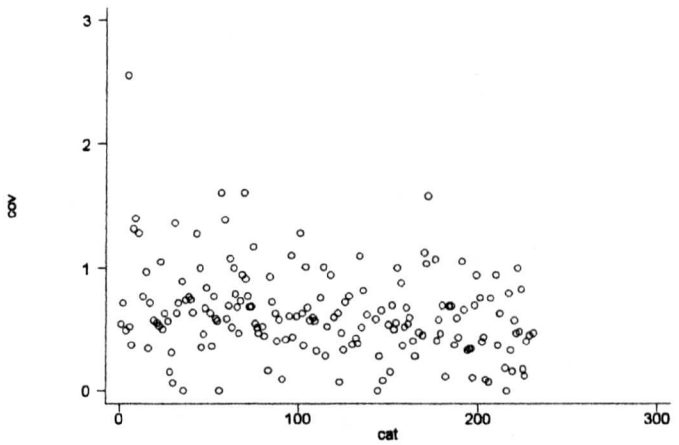
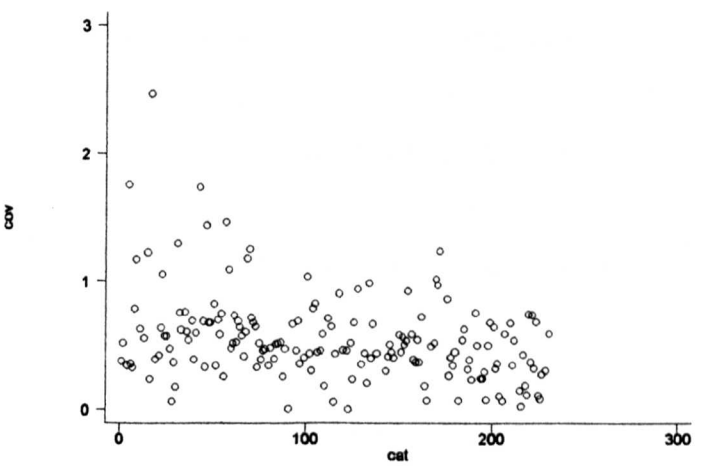


Figure 5.8: A plot of the coefficient of variation of hospital costs against the categories involved



The models developed used a) an identity link and b) a log link. Models incorporating an identity link assume additive effects and consequently enable estimates of the mean additional costs and LOS incurred by infected patients to be taken directly from the model. That is the fitted coefficients associated with HAI directly estimate the additional costs incurred by infected compared to

uninfected patients, or the number of extra days infected patients remain in hospital compared to uninfected patients, after controlling for the effects of all the other factors included in the model. In contrast models incorporating a log link assume multiplicative or proportional effects and as such provide estimates of the ratio of costs and LOS incurred by infected and uninfected patients.

Both simple models which assessed the main effects of the independent variables identified in equation one and two on costs and LOS and more detailed models which assessed two way interactions between HAI and the independent variables were fitted and compared. The statistical significance of each variable in the generalised linear model was determined using the likelihood ratio χ^2 test.

Models were also developed to assess the impact of specific types of infection on costs and LOS. The above approach was repeated substituting the HAI explanatory variable for a variable denoting infections at the following sites: urinary tract, surgical wound, lower respiratory tract, skin, blood, other single site infections not classified elsewhere and multiple sites. The analysis assessed how hospital costs and length of hospital stay varied in patients with these different types of infection compared to uninfected patients, having controlled for factors that may have had impact on length of hospital stay and costs.

5.5.4 Distribution of costs incurred

The distribution of the costs associated with infected and uninfected patients was assessed. Costs were classified into one of 16 categories: hospital overheads; directorate management; capital charges; medical time; nursing care; paramedics and specialist nurses; physiotherapy; surgical interventions; consumables used for specific procedures; antimicrobials; non-antimicrobial drugs; microbiology tests; other pathology tests; endoscopies; radiology; and other tests.

The mean costs incurred by infected and uninfected patients were determined for each category, and the additional costs incurred by infected patients calculated, together with the percentage contribution of each category to the overall additional costs incurred. Generalised linear modelling techniques using the maximum likelihood approach described above were subsequently conducted to assess the impact of HAI on the different cost categories after controlling for the effects of sex, age, specialty, admission type, number of co-morbidities and HAI status.

5.6 Data management

Issues relating to data management have been discussed in the preceding chapter (see section 4.11). The data handling standards applied in the socio-economic burden of HAI study were maintained throughout this work.

5.7 Study timetable

As outlined in the preceding chapter the socio-economic burden of HAI study comprised four phases, all of relevance to this thesis.

Phase 1: This involved a literature review, the development and piloting of the study tools and research methods, and their subsequent modification in the light of the findings of the pilot study. This was conducted over a period of nine months from July 1993 to March 1994.

Phase 2: The main data collection period. This was conducted over a period of 16 months from April 1994 to July 1995.

Phase 3: The validation, analysis and interpretation of the data set for the purposes of the socio-economic burden of HAI study and final Department of Health Report. This was conducted over a period of 13 months from August 1995 to September 1996.

Phase 4: The preparation of the final socio-economic burden of HAI study report and its submission to the Department of Health for internal and external review and subsequent modification. This was conducted over prolonged period of time, culminating with the publication and subsequent release of the final report in January 2000.

These four phases of the project were followed by four further phases which were exclusively concerned with the surgical subset.

Phase 5: Surgical patients were identified and a separate PhD data set which included data variables of relevance to the planned analysis was created. Further data checks were made and the data cleaned as necessary. New data variables relating to the presence or absence of selected risk factors prior to the onset of infection were computed.

Phase 6: The subset of data was analysed. This included a descriptive analysis of the data set, and exploration of the incidence of and key risk factors for infection; and an assessment of the impact of HAI on hospital resources use during the in-patient hospital stay and associated costs.

Phase 7: This involved an exploration of how the costs estimates derived may be incorporated into models to assess the potential benefits of investment in the prevention and control of HAIs.

Phase 8. In parallel with the work described in phases 5-7, a more detailed and in depth review of the literature was conducted, and the thesis drafted.

5.8 Conclusion

This chapter has provided an account of the methods used in this study. The following four chapters present the results of this work. Issues relating to the validity and limitations of the approaches used are discussed in Chapter 11.

CHAPTER 6
SAMPLE CHARACTERISTICS

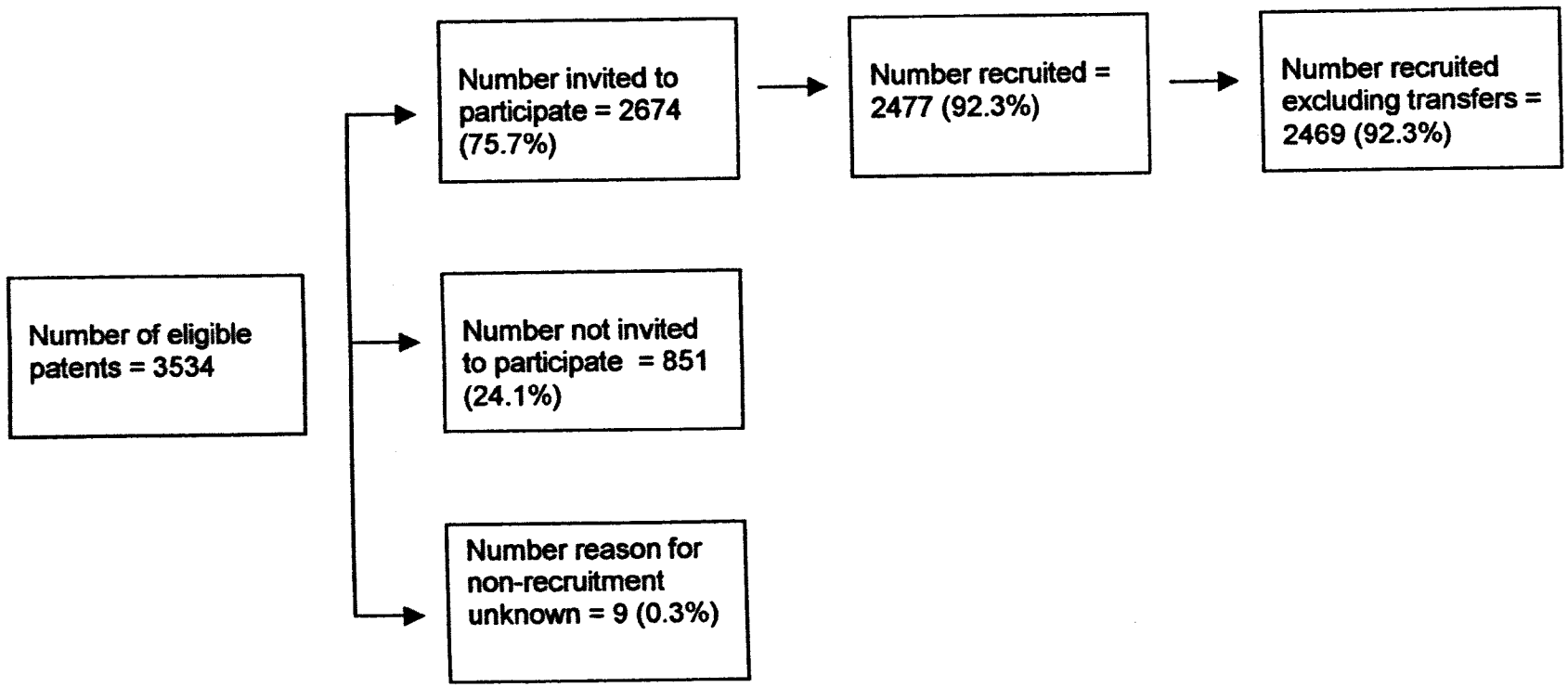
6.1 Introduction

This chapter presents the results of the descriptive analysis which assessed the key characteristics of the sample recruited and how representative they were of all eligible patients. Data relating to the sample size, and time of recruitment are presented first. This is followed by the results of the analysis that explored how a range of patient characteristics were distributed including: age, sex, specialty, admission type, discharge diagnostic group, number of co-morbidities, operations performed, discharge destination and care planned on discharge from hospital.

6.2 Sample size

Between April 1994 and May 1995 3534 adult, non-day case patients admitted to the surgical specialties covered in this study were eligible for recruitment. Of these 2477 (70.1%) patients agreed to participate in this study, 197 (5.6%) declined participation, 851 (24.1%) were eligible for recruitment but were not invited to participate in this study due to time and resource constraints, and in a further nine (0.3%) cases the reason for non-recruitment was not recorded. Of the 2477 surgical patients recruited into the study eight were excluded from the analysis as they were transfers from another ward or hospital and as such differed from the rest of the sample in important respects: 2469 patients were therefore included in the analysis (Figure 6.1).

Figure 6.1: The number of patients eligible for recruitment and the number recruited

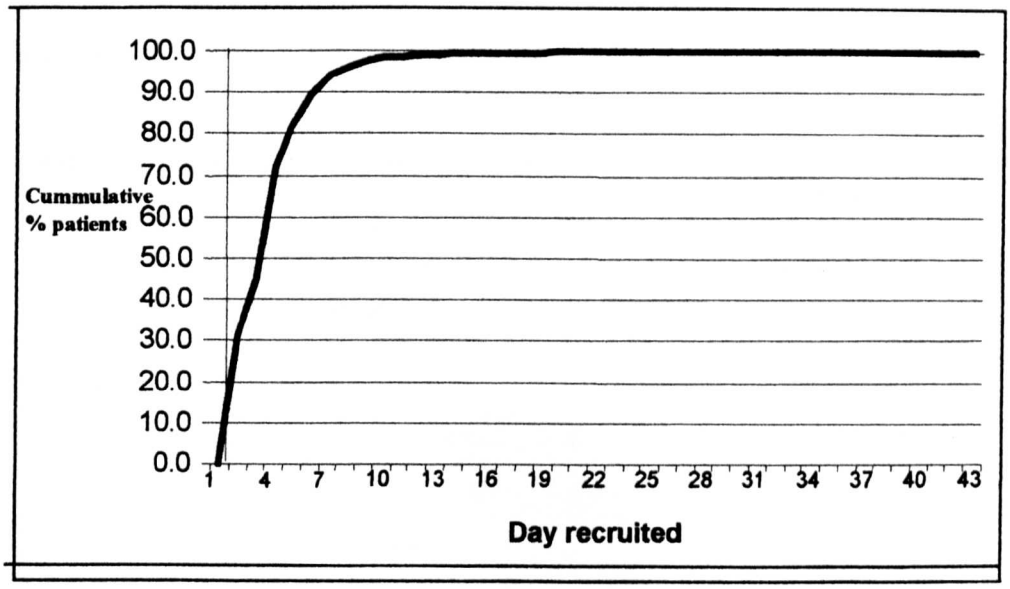


The results of the analysis which compared the age, sex, admission type and admission specialty distributions of patients recruited into the study with eligible patients who were not recruited are reported in Appendix 10. The results indicated that the proportion of patients who were aged 60 years and over was similar for patients in the two cohorts. However there were statistically significant differences with respect to the sex, admission type and admission specialty distributions in the two cohorts of patients. There were fewer male patients, emergency admissions, and general surgical and urology patients in the recruited cohort, and more female patients, elective admissions, and orthopaedic, elderly care, ear nose and throat, obstetric and gynaecology patients. However, the results of the analysis which compared the age, sex, admission type and admission specialty distribution of patients recruited into the study, with that which would have been present if all eligible patients had been recruited, found that the differences between the cohort of recruited patients and the intended cohort of all eligible patients was small. Consequently, since the HAI and non-HAI comparisons controlled for these factors, it is reasonable to assume that the results obtained are generalisable to all eligible patients, despite the significant differences between those recruited and those not recruited.

6.3 Day recruited

Information on the day recruited was available for 2462 (99.7%) patients. The majority of patients were recruited during the early part of their admission: 94% were recruited within the first six days of admission with 31.2% recruited on day one; 13.7% on day two and 27.5% on day three. Figure 6.2 provides further details of when patients were recruited into the study. In those cases where patients were recruited quite late, this was either due to the patients condition precluding them being invited to participate until this time, or due to the research assistant being unable to find a suitable time to recruit the patient until quite late into their admission.

Figure 6.2: The cumulative percentage of patients recruited by day of admission (n= 2462)*



*Note: Information on day recruited was not available for seven patients. These patients were excluded from this analysis.

6.4 Age and sex distribution

Of the 2469 patients recruited into the study 1466 (59.4%) were female and 1003 (40.6%) were male. The minimum age was 18 years and the maximum 94 years, with a mean age of 54.5 years (SD ± 18.4). Table 6.1 provides further details of the age and sex distribution.

Table 6.1: Age and sex distribution

Age group	Male		Female		All patients	
	n	%	n	%	n	%
18-34	126	24.51	388	75.49	514	20.82
35 – 54	217	32.24	456	67.76	673	27.26
55-74	514	54.05	437	45.95	951	38.52
75+	146	44.11	185	55.89	331	13.41
All patients	1003	40.62	1466	59.38	2469	100.00

6.5 Specialty distribution

Figure 6.3 shows the distribution of patients by admission specialty. Overall a greater proportion of patients (36%) were recruited from the general surgical specialty than from the other specialties covered.

Figure 6.3: Distribution of patients by admission specialty

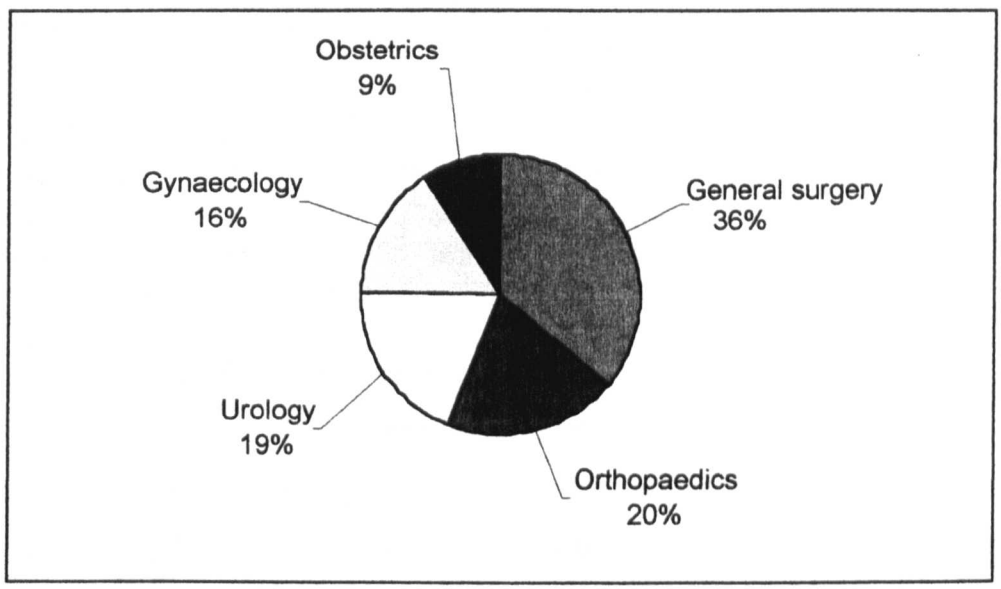


Table 6.2 shows the specialty and sex distribution. It can be seen that the sample included a greater number of female than male patients. This is in part due to the inclusion of two exclusively female specialties (obstetrics and gynaecology). Within the surgical and orthopaedic specialties also more female than male patients were recruited. The only specialty with more male than female patients was urology.

Table 6.2: Sex and specialty distribution

Specialty	n	Male patients		Female patients	
		n	%	n	%
General surgery	884	388	43.9	496	56.1
Orthopaedics	501	219	43.7	282	56.3
Urology	472	396	83.9	76	16.1
Gynaecology	386	0	0.0	386	100.0
Obstetrics	226	0	0.0	226	100.0
All patients	469	1003	40.6	1466	59.4

Table 6.3 shows the age and specialty distribution. Approximately half of the sample (48.1%) were aged 18-54 and the remainder (51.9%) aged over 55 years. As to be expected the gynaecology and obstetric specialties had a younger age profile than the other specialties.

Table 6.3: Age and specialty distribution

Specialty	n	18-34		35 – 54		55-74		75+	
		n	%	n	%	n	%	n	%
General surgery	884	141	16.0	280	31.7	359	40.6	104	11.8
Orthopaedics	501	62	12.4	100	20.0	225	44.9	114	22.8
Urology	472	33	7.0	74	15.7	274	58.1	91	19.3
Gynaecology	386	88	22.8	184	47.7	92	23.8	22	5.7
Obstetrics	226	190	84.1	35	15.5	1	0.4	0	0.0
All patients	2469	514	20.8	673	27.3	951	38.5	331	13.4

6.6 Type of admissions

Table 6.4 shows the number and percentage of patients by admission type. These seven routes of admission were re-classified into two groups, elective and emergency admissions, as indicated in Table 6.4. Of the 2469 patients recruited into the study, 1629 (66%) were elective admissions and 840 (34%) were either urgent or emergency admissions. Table 6.5 shows how the number and percentage of patients admitted via these two different routes varied with specialty. It can be seen that, with the exception of the obstetric specialty, all admission specialties had more elective than emergency admissions.

Table 6.4: Admission type distribution

Admission route	Number of patients	%	Grouped admission category
Elective via pre-admission clinic	365	14.8	Elective
Elective – direct to the ward	1264	51.2	Elective
Urgent –direct to the ward	100	3.9	Emergency
Emergency via A+E	668	27.1	Emergency
Emergency via the OPD	55	2.2	Emergency
Emergency via GP	7	0.3	Emergency
Emergency via community midwife	10	0.4	Emergency
All patients	2469	100	

A+E = Accident and emergency department
OPD = Out-patients Department

Table 6.5: Admission type distribution by admission specialty

Specialty	n	Admission type			
		Elective		Emergency	
		n	%	n	%
General surgery	884	588	66.5	296	33.5
Orthopaedics	501	281	56.1	220	43.9
Urology	472	347	73.5	125	26.5
Gynaecology	386	309	80.1	77	19.9
Obstetrics	226	104	46.0	122	54.0
All patients	2469	1629	66.0	840	34.0

6.7 Re-admissions to hospital

6.7.1 Number of patients classified as 're-admissions'

Patients were classified as a 're-admission' if they had a hospital admission within the last month. Of the 2469 patients recruited into the study 263 patients (10.7%) were classified as re-admissions. Of the remaining 2206 patients, in 10 cases information on re-admission status was not recorded. These patients were assumed not to be re-admissions, the assumption being that if they were, this information would have been recorded. Of the 263 patients classified as re-admissions, in 228 cases (86.7%) the admission was linked to the earlier admission, in 17 cases (6.5%) the admissions were not linked and in 18 cases (6.8%) information on whether this was a linked admission was not recorded.

6.7.2 Characteristics of patients classified as 're-admissions'

Table 6.6 provides an overview of the patient characteristics of patients classified as re-admissions (i.e they were in-patients less than a month prior to the admission in which they were recruited). Of the 263 re-admissions 45 (17.1%) had a HAI, with eight presenting with a HAI on the day of admission, 31 presenting with an HAI at some point during their admission and in the remaining six cases the date of onset of infection was not recorded. Table 6.7 shows the number and percentage of re-admissions presenting with an HAI by admission specialty. Of the 263 patients re-admitted to hospital within a month of discharge three patients died in hospital. All three patients were male surgical patients, two aged 73 years and one 54 years. One patient had a HAI – a BSI acquired during their previous admission.

Table 6.6: Characteristics of patients admitted within month of a previous admission

Patient characteristic	n	%
Sex		
Male	91	34.6
Female	172	65.4
Age group		
18-34	96	36.5
35 – 54	62	23.6
55-74	83	31.6
75+	22	8.4
Specialty		
General surgery	82	31.2
Orthopaedics	28	10.6
Urology	49	18.6
Gynaecology	34	12.9
Obstetrics	70	26.6
Discharge diagnosis group		
Infectious & parasitic diseases	1	0.4
Neoplasms	41	15.6
Endocrine, nutritional & metabolic diseases & immunity disorders	-	-
Diseases of blood & blood forming organs	-	-
Diseases of the nervous system & sense organs	-	-
Diseases of the circulatory system	18	6.8
Diseases of the respiratory system	-	-
Diseases of the digestive system	35	13.3
Diseases of the genitourinary system	42	16
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	77	29.3
Diseases of the skin & subcutaneous tissue	3	1.1
Diseases of the musculoskletal system & connective tissue	14	5.3
Injury & Poisoning	17	6.5
Symptoms, signs & ill-defined conditions; mental disorders & congenital abnormalities	15	5.7
Co-morbidities		
None	147	55.9
One	82	31.2
Two	23	8.7
Three or more	11	4.2
HAI		
No	218	82.9
Yes	45	17.1
In-patient death		
No	256	97.3
Yes	7	2.7

Table 6.7: The distribution of patients admitted within a month of a previous admission to hospital by presence or absence of a HAI and admission specialty

Specialty	n	HAI			
		No		Yes	
		n	%	n	%
General surgery	82	72	27.4	10	3.8
Orthopaedics	28	21	8.0	7	2.7
Urology	49	45	17.1	4	1.5
Gynaecology	34	23	8.7	11	4.2
Obstetrics	70	57	21.7	13	4.9
Total	263	218	82.9	45	17.1

Of the 263 patients who were classified as re-admissions, 70 (26.6%) had already participated in this study. Of these 70 patients seven (2.7%) had a HAI during their previous admission. Three had a SWI, two had UTIs; one had a LRTI; and one a skin infection.

6.8 Distribution of patients by primary discharge diagnosis

Table 6.8 shows the number and percentage of patients by primary discharge diagnosis grouped into 14 disease categories. Seventy-seven per cent of the primary discharge diagnoses fell within just five of the 14 ICD9 categories: diseases of the genitourinary system (23%); diseases of the digestive system (16.9%); neoplasms (14.5%); complications of pregnancy, childbirth and puerperium (10.3%), and diseases of the musculoskeletal system and connective tissue (12.5%).

Table 6.8:The number and percentage of patients by primary discharge diagnosis grouped into 14 diseases categories

Study disease categories 1-14	ICD9 disease categories included in study categories	Title of Categories	Number of patients within each of the 14 disease categories	Percentage of patients within each of the 14 disease category
1	I	Infectious and parasitic disease	13	0.5
2	II	Neoplasms	357	14.5
3	III	Endocrine, nutritional and metabolic diseases and immunity disorders	24	1.0
4	IV	Diseases of blood and blood forming organs	3	0.1
5	VI	Diseases of the nervous system and sense organs	2	0.1
6	VII	Diseases of the circulatory system	150	6.1
7	VIII	Diseases of the respiratory system	6	0.2
8	IX	Diseases of the digestive system	418	16.9
9	X	Diseases of the genitourinary system	569	23.0
10	XI	Complications of pregnancy, childbirth and puerperium Certain conditions originating in the perinatal period	254	10.3
11	XII	Diseases of the skin and subcutaneous tissue	31	1.3
12	XIII	Diseases of the musculoskeletal system and connective tissue	309	12.5
13	XVII	Injury and Poisoning	187	7.6
14	XVI V XIV	Symptoms, signs and ill- defined conditions Mental disorders Congenital abnormalities	146	5.9
All groups			2469	100.0

6.9 Number of co-morbidities

The majority (66.5%) of patients had no co-morbidities; 23.4% had one; 7.0% two and 3.1% three or more co-existing conditions. Table 6.9 shows the number of co-morbidities by specialty.

Table 6.9: The number and percentage of patients by number of co-morbidities and admission specialty

Specialty	Admission specialty										All specialties	
	General surgery		Orthopedic		Urology		Gynaecology		Obstetrics			
	n	%	n	%	n	%	n	%	n	%	n	%
None	492	55.7	365	72.2	361	76.5	322	83.4	102	45.1	1642	66.5
One	263	29.8	84	16.8	77	16.3	54	14.0	100	44.2	578	23.4
Two	79	8.9	41	8.2	27	5.7	8	2.1	18	8.0	173	7.0
Three or more	50	5.7	11	2.2	7	1.5	2	0.5	6	2.7	76	3.1

6.10 Characteristics of patients who had one or more operative procedures

6.10.1 Number of patients who had one or more operations

Of the 2469 patients included in this study 2041 (82.7%) had one or more operations. Of these 2041 patients, 1999 (97.9%) had one operation, 40 (2.0%) had two operations, and two (0.1%) had three operations.

6.10.2 Day of surgery

Data on day of operation were available for 1910 patients. Ninety-five per cent of patients for whom data were available had surgery within 5 days of admission to hospital: 11.8% had surgery on the day of admission; 77.1% on day two; 4.0% on day three; 2.1% on day 4 and 1.4% on day five.

6.10.3 *Characteristics of patients who underwent one or more operations*

Table 6.10 presents the results of the analysis that examined the percentage of patients who underwent one or more operations by age, sex, admission specialty, diagnosis, and number of co-morbidities.

Table 6.10:The number and percentage of patients who had one or more operations

Patient characteristic	n	Patients who had one or more operations		P value
		No.	%	
Sex				
Male	1003	815	81.3	0.126
Female	1466	1226	83.6	
Age group				
18-34	514	416	80.9	0.298
35 – 54	673	570	84.7	
55-74	951	787	82.8	
75+	331	268	81.0	
Specialty				
General surgery	884	682	77.1	<0.001
Orthopaedics	501	433	86.4	
Urology	472	373	79.0	
Gynaecology	386	327	84.7	
Obstetrics	226	226	100.0	
Admission type				
Elective	1629	1559	95.7	<0.001
Emergency	840	482	57.4	
Discharge diagnosis group				
Infectious & parasitic diseases	13	3	23.1	<0.001
Neoplasms	357	322	90.2	
Endocrine, nutritional & metabolic diseases & immunity disorders	24	24	100.0	
Diseases of blood & blood forming organs	3	1	33.3	
Diseases of the nervous system & sense organs	5	0	0.0	
Diseases of the circulatory system	150	131	87.3	
Diseases of the respiratory system	6	5	83.3	
Diseases of the digestive system	418	327	78.2	
Diseases of the genitourinary system	569	493	86.6	
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	254	241	94.9	
Diseases of the skin & subcutaneous tissue	31	25	80.6	
Diseases of the musculoskletal system & connective tissue	309	287	92.9	
Injury & Poisoning	187	142	75.9	
Symptoms, signs & ill-defined conditions; mental disorders & congenital abnormalities	146	40	27.4	
Co-morbidities				
None	1642	1396	85.0	<0.001
One	578	452	78.2	
Two or more	249	193	77.5	

The proportion of patients who had one or more operations varied little with sex or age category: 81.3% of males and 83.6% of females had one or more operations and for all age categories at least 80% had one or more operations. There was some variation with admission specialty. The observed variation was significant (p=<0.001). As expected, 100% of patients admitted to the obstetric specialty had an operation. The study was limited to patients who had a caesarean section. In the other specialties the proportion of patients who had an operation varied from 77.1% (general surgery) to 86.4% (orthopaedics). A significantly higher proportion of elective admissions (95.7%) than emergency admissions (57.4%) had one or more operations (p=<0.001). The proportion of patients who had one or more operations varied with primary discharge diagnosis and varied slightly with number of co-morbidities.

American Society of Anaesthesiologists scores (ASA) scores were reported for 1556 patients. Of these patients 699 (25.6%) had a score of one; 667 (42.9%) had a score of two; 174 (11.2%) had a score of three, nine (0.6%) had a score of four and seven (0.4%)had a score of five.

6.10.4 Types of surgery performed

The analysis of types of procedure performed was based on the Office of Population Census and Survey classification of operative procedures system (fourth addition)[231] and limited to the frequency of the first procedure reported. It was assumed that the first reported procedure represented the primary operative procedure undertaken. The research assistants were instructed to report the primary procedure first, and in those cases where data on procedure group had been derived direct from the Patient Administration System database it was usual practice to report the primary procedure first. Of the 2025 initial operations for which data on procedure were available, 1414 (69.8%) involved one procedure, 388 (19.2%) involved two procedures, 163 (8.0%) involved three, 45 (2.2%) involved four, nine (0.2%) involved five, and six (0.3%) involved six procedures.

Table 6.11 provides details of the number and overall percentage of primary procedures, classified within the broad operation categories, performed. The results reported in Table 6.11 indicated that almost 80% of operations involved primary procedures classified within six broad operation categories: operations involving bones and joints (18.5%); urinary system (17.6%), upper female genital tract (12.0%), lower digestive tract (11.1%), female genital tract associated with pregnancy and childbirth (11.1%) and soft tissues (8.8%). Further details of the specific types of procedures performed are presented in Appendix 11.

Table 6.11:The number and percentage of patients undergoing primary procedures classified according to the Office of Population Censuses and Surveys listed categories

OPCS operation category	No. & % of patients whose primary procedure fell within each category	
	No.	%
A Nervous system	10	0.5
B Endocrine system and breast	104	5.1
C Eye	0	0.0
D Ear	0	0.0
E Respiratory tract	1	0.0
F Mouth	7	0.3
G Upper digestive tract	23	1.1
H Lower digestive tract	225	11.1
J Other abdominal organs - principally digestive	80	4.0
K Heart	0	0.0
L Arteries and Veins	56	2.8
M Urinary	356	17.6
N Male genital organs	26	1.3
P Lower female genital	60	3.0
Q Upper female genital	242	12.0
R Female genital tract associated with pregnancy and childbirth	224	11.1
S Skin	23	1.1
T Soft tissue	179	8.8
V Bones and joints of skull and spine	15	0.7
W Other bones and joints	375	18.5
X Miscellaneous operations	10	0.5
Y Subsidiary classification of methods of operation	8	0.4
Z Subsidiary classification of sites of operations	1	0.0

Note: analysis was based on 2025 patients for whom data on primary procedure was available.

6.11 In-patient deaths

Twenty-one patients (0.9%) died during the in-patient period. Eleven patients were female, ten patients male. Overall 14 (66.7%) were surgical patients and the remaining seven orthopaedic patients. Eighty-eight per cent of deaths occurred in patients who had one or more operations. The mean age was 74 years with a minimum age of 32 and maximum age of 93 years. Four (19%) had no co-morbidities; six (28.6%) had one co-morbidity; two (9.5%) had two co-morbidities and nine (42.9%) had three or more co-morbidities. Eight (38.1%) patients had an HAI identified during their hospital stay. Of these one had a UTI, two a LRTI, one a BSI, one an infection at a site not classified elsewhere, one a BSI and an infection at a site not specified elsewhere and one a LRTI and an infection at another site. Overall patients who acquired an infection while in hospital were 4.3 (95% CI: 1.6, 11.2) times more likely to die than uninfected patients.

6.12 Discharge destination and follow up care

The majority (97.6%) of patients were discharged home. Table 6.12 provides details of the discharge destination.

Table 6.12: Distribution of patients by discharge destination

Discharge destination	n	%
Home	2410	97.6
Other ward>1week	7	0.3
Other ward <1 week	2	0.1
Other hospital> 1 week	13	0.5
Other hospital<1 week	2	0.1
Hospice	2	0.1
Convalescent home	1	0.0
Nursing home	2	0.1
Relatives	9	0.4
Died	21	0.9
Total	2469	100

6.13 Services organized on discharge from hospital

6.13.1 Transport.

Of the 2469 patients recruited into the study 42 (1.7%) required an ambulance to take them home and 32 (1.3%) required a hospital car. The remaining 2395 (97%) patients did not require transport. Table 6.13 shows the age distribution of patients who utilised this service and table 6.14 the specialty distribution. The use of hospital transport (ambulance or car) was found to increase with increasing age and be highest for patients admitted to the orthopaedic specialty.

Table 6.13: The number and percentage of patients requiring NHS transport home by age group

		Transport			
		Ambulance		Hospital car	
Age group		n	%	n	%
18-34	(n= 514)	0	0.0	1	0.2
35 – 54	(n= 673)	2	0.3	0	0.0
55-74	(n= 951)	17	1.8	18	1.9
75+	(n= 331)	23	7.0	13	3.9
All patients	(n= 2469)	42	1.7	32	1.3

Table 6.14: The number and percentage of patients requiring NHS transport home by admission specialty

Specialty		Transport			
		Ambulance		Hospital car	
		n	%	n	%
General surgery	(n = 884)	9	1.0	6	0.7
Orthopaedics	(n = 501)	26	5.2	23	4.6
Urology	(n = 472)	7	1.8	3	0.8
Gynaecolgy	(n = 386)	0	0.0	0	0.0
Obstetrics	(n = 226)	0	0.0	0	0.0
All specialties	(n = 2469)	42	1.7	32	1.3

6.13.2 Follow up care

In a number of cases follow-up care was organized for patients prior to discharge. Tables 6.15 and 6.16 shows the number and percentage of patients for whom follow up care was arranged by type of care and admission specialty.

Table 6.15: The number and percentage of patients for whom community based follow-up care was organized by type of care and specialty

	General surgery (n= 884)		Orthopaedics (n= 501)		Urology (n=472)		Gynaecology (n=386)		Obstetrics (n = 226)		All patients (n=2469)	
	n	%	n	%	n	%	n	%	n	%	n	%
District nurse	97	11.0	55	11.0	96	20.3	5	1.3	0	0.0	253	10.2
General practitioner	25	2.8	11	2.2	11	2.3	5	1.3	0	0.0	52	2.1
Practice nurse	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	1	0.0
Elderly support team	2	0.2	12	2.4	1	0.2	0	0.0	0	0.0	15	0.6
CTT	0	0.0	1	0.2	0	0.0	0	0.0	0	0.0	1	0.0
Continence advisor	2	0.2	2	0.4	6	1.3	0	0.0	0	0.0	10	0.4
Macmillan nurse	6	0.7	0	0.0	4	0.8	0	0.0	0	0.0	10	0.4
Stoma nurse	1	0.1	1	0.2	1	0.2	0	0.0	0	0.0	3	0.1
Diabetic nurse	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	1	0.0
Hospital at home team	0	0.0	17	3.4	0	0.0	0	0.0	0	0.0	17	0.7
Plastic surgery dressing clinic	0	0.0	1	0.2	0	0.0	0	0.0	0	0.0	1	0.0
Physiotherapy	0	0.0	12	2.4	0	0.0	0	0.0	0	0.0	12	0.5
Occupational therapy	0	0.0	3	0.6	0	0.0	1	0.3	0	0.0	4	0.2
Social worker	10	1.1	13	2.6	7	1.5	2	0.5	0	0.0	32	1.3
Home help	5	0.6	3	0.6	6	1.3	1	0.3	0	0.0	15	0.6
Meals on wheels	5	0.6	1	0.2	10	2.1	0	0.0	0	0.0	16	0.6

CTT – community therapy team

Table 6.16: The number and percentage of patients for whom hospital based follow-up care was organized by type of care and specialty

	General surgery (n= 884)		Orthopedics (n= 501)		Urology (n=472)		Gynecology (n=386)		Obstetrics (n = 226)		All patients (n=2469)	
	n	%	n	%	n	%	n	%	n	%	n	%
Out-patient appointment	588	66	439	87.6	347	73.5	274	71.0	1	0.4	1649	66.8
ECG	2	0.2	2	0.4	2	0.4	1	0.3	0	0.0	6	0.2
Endoscopy	1	0.1	0	0.0	1	0.2	0	0.0	0	0.0	2	0.1
TWOC	2	0.2	0	0.0	49	10.4	13	3.4	0	0.0	64	2.6
Lithotripsy	0	0.0	0	0.0	1	0.2	0	0.0	0	0.0	1	0.1
Day hospital	8	0.9	3	0.6	9	1.9	0	0.0	0	0.0	9	0.4
Other	9	1.0	3	0.6	13	2.8	0	0.0	1	0.0	30	1.2

ECG – electro-cardiogram; TWOCC – Trial without catheter

6.14 Conclusion

In this chapter the results of the analysis that explored the general characteristic of the data set have been presented. The distribution of patients by age, sex, specialty, admission type, admission specialty, primary discharge diagnosis group and number of co-morbidities have been presented, as has the mortality rate observed and the follow up care organised for these patients. The following chapter will examine the incidence of HAIs occurring in this sample of patients.

CHAPTER 7
THE INCIDENCE OF AND RISKS FACTORS FOR HAI: RESULTS

7.1 Introduction

This chapter presents the results of the descriptive analysis of the incidence of HAIs occurring in surgical patients and the results of the multivariable analysis that identified independent risk factors for HAI. The analysis is limited to those infections that presented during the in-patient period. The chapter begins with an exploration of the overall incidence of HAI as defined by two alternative definitions of incidence, and how the incidence varies with selected patient characteristics (section 7.2). Data on the day the primary infection presented are then presented in section 7.3. The results of the analysis that explored independent risk factors for HAI are presented in section 7.4 and sections 7.5 – 7.6 present the results of the analysis that explored the incidence of specific types of HAI, and the day different types of infections presented. Finally sections 7.7–7.9 present the results of the analysis that examined how the incidence of the three most frequent types of infections, urinary tract, surgical wound and lower respiratory tract infections, varied with selected patient characteristics and the results of the analysis that explored independent risk factors for these infections.

7.2 The incidence of HAI

The incidence of HAI was assessed according to two alternative definitions:

- the number of patients who presented with one or more HAIs expressed as a percentage of the number of patients discharged

- the number of primary HAIs that presented during the in-patient period/1000 patient days at risk

The estimates of the incidence used only HAIs which were both acquired and identified during the hospital stay. Patients admitted with an HAI who did not acquire a second infection were excluded from the numerator and included in the denominator. There were nine patients in this category. In a further seven cases data on the day of presentation were not available. In these seven cases it was assumed that the patient acquired their infection at some point during their admission and that they were not admitted with the infection. This assumption was based on the fact that it is likely that if the patient had been admitted with an infection related to a previous admission the research assistant would have entered this information on the data collection sheet at the time of recruitment.

7.2.1 The number of patients who presented with one or more HAIs expressed as a percentage of the number of patients discharged

One hundred and eighty-four patients presented with one or more HAIs during the in-patient period: an incidence rate of 7.5% (95% CI: 6.4, 8.6). Table 7.1 shows how the incidence of HAI varied with key patient characteristics. The incidence of HAIs presenting during the in-patient period was higher in female patients, increased with increasing age, was higher in patients classified as emergency admissions when compared to elective admissions, and was highest in patients admitted to the gynaecology specialty, followed by patients admitted to the obstetric, orthopaedic, urology and surgical specialties. The incidence of HAI also varied with primary discharge diagnosis, although the confidence intervals around many of the disease categories were wide, and was higher in patients with co-morbidities than in those patients with no co-morbidities. The incidence of HAI was higher in patients who had diabetes mellitus listed as a co-morbidity although this was not found to be significant ($p= 0.620$), and was significantly higher in patients who had one or more operations.

Table 7.1: The incidence of HAIs presenting in surgical patients during the hospitalised phase by selected characteristics

Characteristic	n	HAI		IR (95% CI)	P value
		No	Yes		
Sex					
Male	1003	952	51	5.1 (4.3 to 7.3)	<0.001
Female	1466	1333	133	9.1 (7.6 to 10.6)	
Age					
18 –34	514	486	28	5.4 (3.9 to 8.0)	0.017
35-54	673	631	42	6.2 (4.5 to 8.3)	
55-74	951	872	79	8.3 (16.8 to 10.5)	
75+	331	296	35	10.6 (8.0 to 15.1)	
Admission type					
Elective	1629	1520	109	6.7 (5.9 to 8.1)	0.044
Emergency	840	765	75	8.9 (7.1 to 11.1)	
Specialty					
General surgery	868	815	53	6.1 (4.6 to 7.9)	<0.001
Orthopaedics	501	464	37	7.4 (5.2 to 10.4)	
Urology	472	448	24	5.1 (3.9 to 8.4)	
Gynaecology	386	337	49	12.7 (9.9 to 16.8)	
Obstetrics	226	205	21	9.3 (6.2 to 14.4)	
Primary diagnosis					
Infectious & parasitic	13	12	1	7.7 (0.2 to 36.0)	0.009
Neoplasms	357	329	28	7.8 (5.3 to 11.1)	
Endocrine, nutritional & metabolic diseases & immunity disorders	24	20	4	16.7 (4.7 to 37.4)	
Diseases of blood & blood forming organs	3	3	0	0 (0.0 to 0.0)	
Diseases of the nervous system & sense organs	2	2	0	0 (0.0 to 0.0)	
Diseases of the circulatory system	150	142	8	5.3 (2.3 to 10.2)	
Diseases of the respiratory system	6	4	2	33.3 (4.3 to 77.7)	
Diseases of the digestive system	418	397	21	5.0 (3.1 to 7.6)	
Diseases of the genitourinary system	569	521	48	8.4 (6.6 to 11.4)	
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	254	231	23	9.1 (6.1 to 13.7)	
Diseases of the skin & subcutaneous tissue	31	28	3	9.7 (2.5 to 26.9)	
Diseases of the musculoskletal system & connective tissue	309	297	12	4.2 (2.6 to 7.1)	
Injury & poisoning	187	164	23	12.3 (9.7 to 20.3)	
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	146	135	11	7.5 (3.8 to 13.1)	
Number of co- morbidities					
None	1642	1538	104	6.3 (5.2 to 7.6)	<0.001
One	578	530	48	8.3 (6.4 to 11.1)	
Two	173	159	14	8.1 (4.4 to 13.1)	
Three of more	76	58	18	23.7 (13.8 to 33.8)	
Diabetes mellitus listed as a co-morbidity					
No	2378	2202	176	7.4 (6.4 to 8.5)	0.620
Yes	91	83	8	8.8 (3.9 to 16.6)	
One or more operations					
No	428	409	19	4.4 (2.7 to 6.8)	0.009
Yes	2041	1876	165	8.1 (6.9 to 9.3)	

IR – incidence rate; CI –confidence interval

The results presented in Table 7.2 show how the incidence of HAI varied with primary operative procedure classified according to the Office of Population Census and Surveys Operation Classification System (fourth edition).[231] The results presented show how the incidence varied with primary procedure classified according to the broad body system groups. The variation in incidence rates observed for the different procedure categories was highly significant (p=<0.001). The analysis was limited to 2024 patients for whom data on primary operative procedure were available. The number of patients in some of the subgroups was small and as such it is difficult to draw strong conclusions. However, if categories which include more than 20 patients are considered, it can be seen that the highest incidence rates were observed in patients who had operations involving the upper digestive tract (IR 34.8%, 95% CI: 16.4%, 57.3%), the lower female genital tract (IR 18.3%, 95% CI: 9.5%, 30.4%), the skin (IR 13%, 95% CI: 2.8%, 33.6%) and the upper female genital tract (IR 12.0%, 95%CI: 8.2%, 16.8%).

More detailed analysis examined how the HAI incidence rate varied with the specific type of primary procedure performed. The results are presented in Appendix 11. Amongst patients who had a primary procedure involving the upper digestive tract, the incidence of HAI was highest in patients whose primary procedure involved the ileum in the form of surgery such as the excision of the ileum or creation of an artificial opening in the ileum (57.1%) and in patients who had a total or partial excision of the stomach and/or oesophagus (37.5%). Amongst those patients whose surgery involved the lower female genital tract, the highest incidence was observed in patients whose primary procedure involved a repair of a vaginal prolapse (19.3%). In those patients whose surgery involved the upper female genital tract, the highest incidence was observed in patients whose primary procedure was a hysterectomy (14.9%).

Table 7.2: Incidence of HAI by primary operative procedure category

Operation category		n	HAI		IR (%) (95% CI)
			No	Yes	
A	Nervous system	10	10	0.0	0.0 (0.0 , 30.8)
B	Endocrine system and breast	104	100	4.0	3.8 (1.1, 9.6)
C	Eye	0	0	0.0	0.0
D	Ear	0	0	0.0	0.0
E	Respiratory tract	1	0	1.0	100.0 (2.5, 100.0)
F	Mouth	7	6	1.0	14.3 (0.4, 57.9)
G	Upper digestive tract	23	15	8.0	34.8 (16.4, 57.3)
H	Lower digestive tract	225	211	14.0	6.2 (3.4, 10.2)
J	Other abdominal organs - principally digestive	80	75	5.0	6.3 (2.1, 14.0)
K	Heart	0	0	0.0	0.0 –
L	Arteries and Veins	56	51	5.0	8.9 (3.0, 19.6)
M	Urinary	355	334	21.0	5.9 (3.6, 8.9)
N	Male genital organs	26	26	0.0	0.0 (0.0, 13.2)
P	Lower female genital	60	49	11.0	18.3 (9.5, 30.4)
Q	Upper female genital	242	213	29.0	12.0 (8.2, 16.8)
R	Female genital tract associated with pregnancy and childbirth	224	205	19.0	8.5 (5.2, 12.9)
S	Skin	23	20	3.0	13.0 (2.8, 33.6)
T	Soft tissue	179	168	11.0	6.1 (3.1, 10.7)
V	Bones and joints of skull and spine	15	15	0.0	0.0 (0, 21.8)
W	Other bones and joints	375	352	23.0	6.1 (3.9, 9.1)
X	Miscellaneous operations	10	7	3.0	30.0 (6.7, 65.2)
Y	Subsidiary classification of methods of operation	8	8	0.0	0.0 (0.0, 36.9)
Z	Subsidiary classification of sites of operations	1	1	0.0	0.0 (0.0, 98.0)

Note: Based on 2024 patients for whom operation data available.

IR – incidence rate; CI –confidence interval

Further analysis examined whether the incidence of HAI varied with Body Mass Index (BMI). This aspect of the analysis was limited to 1588 patients for whom data on both height and weight were available. Patients were classified into three groups: patients with a BMI of less than 20; patients with a BMI of 20-29; and patients with a BMI of greater than 30. The incidence of HAI was found to vary with BMI category as follows: 10.3% (95% CI: 5.5 to 17.4) of the 115 patients who had a BMI of less than 20 acquired one or more infections, compared to 6.0% (4.7 to 7.4) of the 74 patients who had a BMI of 20-29 and 6.4% (3.0 to 8.7) of the 280 patients with a BMI of 30 or more. The variation in rates was not found to be significant (p=0.149)

7.2.2 The number of primary HAIs/1000 patient days at risk

The number of days at risk was calculated as the number of days from admission to either the day prior to the day the primary infection was identified, or date of discharge, depending on which came first.

As previously indicated 184 patients acquired and presented with an infection during their admission. Of these seven did not have a date of onset recorded. These seven patients were excluded from this analysis. The remaining 177 infected patients had a total of 1,280 days at risk and uninfected patients had 15,149 days at risk. The overall number of days at risk was therefore 16,429 days, giving an incidence density of 10.8 (95% CI: 9.2, 12.5) infections per 1000 patient days at risk.

Table 7.3 shows how the incidence of HAI per 1000 patient days at risk varied with key patient characteristics.

Table 7.3 The number of patients presenting with one or more HAIs in hospital per 1000 patient days at risk

Patient characteristic	n	No. of days at risk		Total No. of days at risk	No. of pts with one of more HAIs	Incidence density (95% CI)	P value
		Pts with an HAI (a)	Pts with no HAI (b)	(a+b) = (c)	(d)	(d/c)*1000	
Sex							
Male	1001	430	5636	6066	49	8.1 (5.9 , 10.7)	0.0093
Female	1461	850	9513	10363	128	12.4 (10.3 , 14.7)	
Age group							
18 –34	514	156	2921	3077	28	9.1 (6.0, 13.2)	0.7924
35-54	672	215	3477	3692	41	11.1 (8.0, 15.1)	
55-74	946	600	5981	6581	74	11.2 (8.8, 14.1)	
75+	330	309	2770	3079	34	11.0 (7.6, 15.4)	
Admission specialty							
General surgery	984	499	4481	4980	53	10.6 (8.0, 13.9)	0.0001
Orthopaedics	496	286	4768	5054	32	6.3 (4.3, 8.9)	
Urology	472	153	2304	2457	24	9.8 (6.3, 14.5)	
Gynaecology	384	236	2068	2304	47	20.4 (15.0, 27.1)	
Obstetrics	226	106	1528	1634	21	12.9 (8.0, 19.6)	
Admission type							
Elective	1627	613	9126	9739	107	11.0 (9.0, 13.3)	0.7505
Emergency	835	667	6023	6690	70	10.5 (8.2, 13.2)	
Primary diagnosis							
Infectious and parasitic Disease	13	2	46	48	1	20.8 (0.5, 116.1)	0.0009
Neoplasms	357	206	2192	2398	28	11.7 (7.8, 16.9)	
Endocrine, nutritional & metabolic diseases & immunity disorders	24	12	97	109	4	36.7 (10.0, 93.9)	
Diseases of blood & blood forming organs	3	0	13	13	0	0.0 (0.0, 283.7)	
Diseases of the nervous system & sense organs	2	0	7	7	0	0.0 (0.0, 526.8)	
Diseases of the circulatory system	150	129	706	835	8	9.6 (4.1, 18.9)	
Diseases of the respiratory system	6	19	28	47	2	42.6 (5.2, 153.7)	
Diseases of the digestive system	418	127	1937	2064	21	10.2 (6.3, 15.6)	
Diseases of the genitourinary system	568	260	2799	3059	47	15.4 (11.3, 20.4)	
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	254	114	1681	1795	23	12.8 (8.1, 19.2)	
Diseases of the skin & subcutaneous tissue	31	23	126	149	3	20.1 (4.1, 58.8)	
Diseases of the musculoskletal system & connective tissue	309	91	3122	3213	12	3.7 (1.9, 6.5)	
Injury & poisoning	181	171	1616	1787	17	9.5 (5.5, 15.2)	
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	146	126	779	905	11	12.2 (6.1, 21.7)	
Co-morbidities							
None	1637	550	9568	10118	99	9.8 (8.0, 11.9)	0.0042
One	576	378	3690	4068	46	11.3 (8.3, 15.1)	
Two	173	203	1378	1581	14	8.9 (4.8, 14.9)	
Three or more	76	149	513	662	18	27.2 (6.1, 43.0)	
Diabetes listed as a co-morbidity							
No	2371	1179	14370	15549	169	10.9 (9.3, 12.6)	0.6119
Yes	91	101	779	880	8	9.1 (3.9, 17.9)	

CI –confidence interval

7.3 Day of presentation

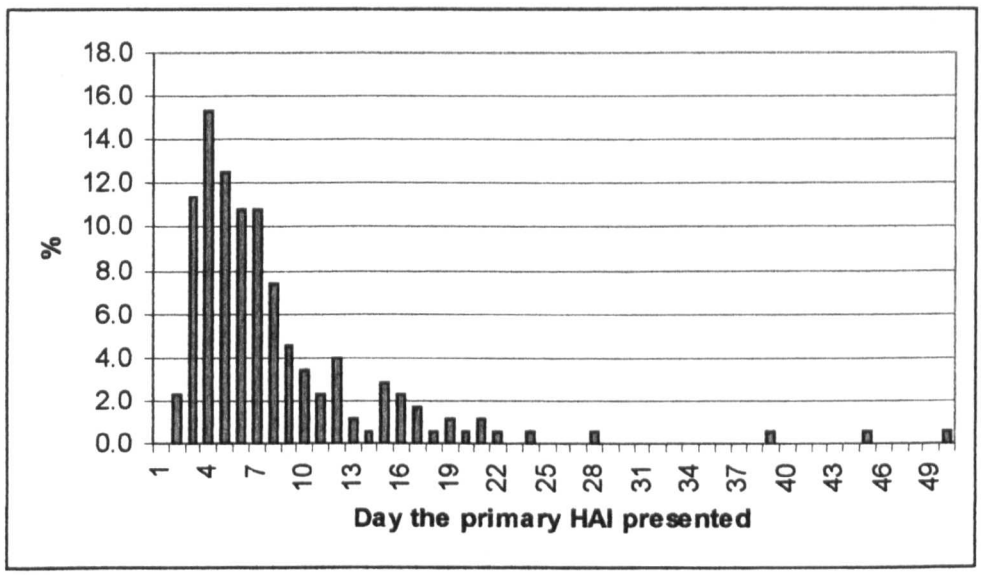
Table 7.4 shows the number and percentage of primary infections by the day the infection was identified, and Figure 7.1 provides a graphical presentation of the proportion of infections presenting by day of admission. Data on the day the HAI presented was available for 177 of the 184 patients who were not admitted with an HAI, but acquired one or more infections whilst in hospital which presented during the in-patient phase. The results presented in Table 7.4 indicate that over 50% of the infected patients presented with their primary infection within six days of admission and 75% within nine days of admission.

Table 7.4: The day the primary HAI presented*

Day primary HAI presented	Number of HAIs	% of HAIs	Cumulative %
2	4	2.3	2.3
3	21	11.9	14.1
4	27	15.3	29.4
5	22	12.4	41.8
6	19	10.7	52.5
7	19	10.7	63.3
8	13	7.3	70.6
9	8	4.5	75.1
10	6	3.4	78.5
11	4	2.3	80.8
12	7	4.0	84.7
13	2	1.1	85.9
14	1	0.6	86.4
15	5	2.8	89.3
16	4	2.3	91.5
17	3	1.7	93.2
18	1	0.6	93.8
19	2	1.1	94.9
20	1	0.6	95.5
21	2	1.1	96.6
22	1	0.6	97.2
23	0	0.0	97.2
24	1	0.6	97.7
25-27	0	0.0	97.7
28	1	0.6	98.3
29	0	0.0	98.3
39	1	0.6	98.9
40-44	0	0.0	98.9
45	1	0.6	99.4
47-49	0	0.0	99.4
50	1	0.6	100.0
Total	177	100.0	

*The analysis was limited to 177 of the 184 HAIs presenting during the in-patient phase.
In seven cases data on day of presentation was not available.

Figure 7.1: The day the primary HAI presented



7.4. Independent risk factors for HAI

The preceding sections have presented the results of the analysis that examined how the incidence of HAI varied with different incidence measures and with selected patient characteristics. In this section the results of the multi-variable logistic regression analysis that identified independent risk factors for infection are presented. The factors included in the analysis were those listed in Tables 7.5 and 7.6. Details of the methods used can be found in section 5.5.2 of Chapter 5.

Table 7.5 presents the results of the single variable analysis and Table 7.6 the results of the multivariable analysis. The results of the single variable analysis indicate that with the exception of diabetes, the odds of acquiring an HAI whilst in hospital vary significantly with all the factors included in the analysis. Females were found to be at greater risk of acquiring an infection than males; the risk increased with age and increasing number of co-morbidities; emergency admissions were at higher risk than elective admissions; the risk was greatest amongst gynaecology patients and higher amongst patients who had received antibiotic prior to the onset of an infection. The results of the multivariable analysis indicted that this pattern remained, and with the exception of sex, antibiotics and diabetes the odds of acquiring an infection varied significantly with all the factors included in the analysis.

Table 7.5: The odds of acquiring a HAI by key patient characteristics (single variable analysis)

Patient characteristic	n	HAI		Odds ratio (95% CI)	P value
		No	Yes		
Sex					
Male	1003	952	51	1.0	0.0002
Female	1466	1333	133	1.9 (1.3 , 2.6)	
Age group					
18 –34	514	486	28	1.0	0.0076
35-54	673	631	42	1.2 (0.7 , 1.9)	
55-74	951	872	79	1.6 (1.0 , 2.5)	
75+	331	296	35	2.1 (1.2 , 3.4)	
Admission type					
Elective	1629	1519	110	1.0	0.003
Emergency	840	766	74	1.4 (1.0 , 1.9)	
Specialty					
General surgery	884	831	53	1.0	0.0003
Orthopaedics	501	464	37	1.3 (0.8 , 1.9)	
Urology	472	448	24	0.9 (0.5 , 1.4)	
Gynaecology	386	337	49	2.3 (1.5 , 3.4)	
Obstetrics	226	205	21	1.6 (1.0 , 2.7)	
Number of co-morbidities					
None	1642	1538	104	1.0	0.0016
One	579	531	48	1.3 (0.9 , 1.9)	
Two or more	249	235	14	2.2 (1.4 , 3.3)	
Antibiotics pre HAI- any route					
No	1002	948	54	1.0	0.0074
Yes	1467	1338	129	1.7 (1.2 , 2.4)	
Diabetes					
No	2378	2202	176	1.0	0.6289
Yes	91	83	8	1.2 (0.6 , 2.5)	
Operation					
No	428	409	19	1.0	0.0056
Yes	2041	1876	165	1.9 (1.2 , 3.1)	

CI – confidence interval

Table 7.6: The odds of acquiring a HAI by key patient characteristics (multivariable analysis)

Patient characteristic	n	HAI		Odds ratios (95% CI)	P value
		No	Yes		
Sex					
Male	1003	952	51	1.0	0.061
Female	1466	1333	133	1.5 (1.0 , 2.3)	
Age group					
18 –34	514	486	28	1.0	<0.0001
35-54	673	631	42	1.7 (1.0 , 3.1)	
55-74	951	872	79	3.4 (1.9 , 6.3)	
75+	331	296	35	4.2 (2.1 , 8.1)	
Admission type					
Elective	1629	1519	110	1.0	<0.0001
Emergency	840	766	74	2.3 (1.6 , 3.4)	
Specialty					
General surgery	884	831	53	1.0	<0.0001
Orthopaedics	501	464	37	0.9 (0.6 , 1.5)	
Urology	472	448	24	0.9 (0.5 , 1.6)	
Gynaecology	386	337	49	3.0 (1.8 , 4.8)	
Obstetrics	226	205	21	1.9 (0.9 , 3.9)	
Number of co-morbidities					
None	1642	1538	104	1.0	0.0118
One	579	531	48	1.3 (0.9 , 2.0)	
Two or more	249	235	14	2.1 (1.3 , 3.4)	
Diabetes					
No	2378	2202	176	1.0	0.4601
Yes	91	83	8	0.7 (0.3 , 1.7)	
Antibiotics pre HAI- any route					
No	1002	948	54	1.0	0.1340
Yes	1467	1338	129	1.3 (0.9 , 1.8)	
Operation					
No	428	409	19	1.0	0.0002
Yes	2041	1876	165	2.7 (1.5 , 4.7)	

CI – confidence interval

7.5 The incidence of specific types of HAI

Whilst 184 patients acquired and presented with one or more HAIs during the in-patient phase, overall 208 infections were identified during this time period. UTIs were the most frequent type of infection accounting for 48.1% of the infections observed, followed by SWIs and LRTIs (Table 7.7).

Table 7.7: The number, percentage and incidence of HAI by site of infection

Type of HAI	Number of infections	Proportion of infections identified (%)	Incidence of HAI (%) (95% CI)
UTI	100	48.1	4.1 (3.3 , 4.9)
LRTI	23	11.1	0.9 (0.6 , 1.4)
SWI	40	19.2	1.6 (1.2 , 2.2)
BSI	4	1.9	0.2 (0.0 , 0.4)
Skin	16	7.7	0.6 (0.4 , 1.1)
Other	25	12.1	1.0 (0.7 , 1.5)

UTI – urinary tract infection; LRTI – lower respiratory tract infection; SWI - surgical wound infection; BSI - bloodstream infection
CI – confidence interval

7.6 Day of presentation of different types of infection

Table 7.8 shows the number and percentage of infections by the day the infection was identified. Data on the day the HAI presented was not available for all HAIs. Details of the number of infections included for each site specific analysis are presented at the bottom of the table. The results presented in Table 7.8 indicate that for all sites of infection at least 50% of the infections identified presented within eight days of admission, and with the exception of skin infections 75% or more of each type of infection presented within two weeks of admission.

Table 7.8: The day HAIs presented by site of infection

Day HAI presented	UTI			LRTIs			SWI			BSIs			Skin infections			Infections at other sites		
	No	% of UTIS	Cum %	No	% of LRTIs	Cum %	No	% of SWIs	Cum %	No	% of BSIs	Cum %	No	% of skin	Cum %	No	%	Cum %
2	3	3.0	3.0	0	0.0	0.0	0.0	0.0	0.0	1	25.0	25.0	1	6.25	6.25			
3	15	15.2	18.2	3	8.7	8.7	0.0	0.0	0.0	0	0.0	25.0	1	6.25	12.5			
4	13	13.1	31.3	7	30.4	39.1	2	5.9	5.9	0	0.0	25.0	2	12.5	25	5	21.7	21.7
5	17	17.2	48.5	2	8.7	47.8	4	11.8	17.6	1	25.0	50.0	3	18.75	43.8	1	4.3	26.1
6	6	6.1	54.5	3	13.0	60.9	1	2.9	20.6	0	0.0	50.0	1	6.25	50.0	5	21.7	47.8
7	11	11.1	65.7	2	8.7	69.6	7	20.6	41.2	0	0.0	50.0	0	0.0	50.0	3	13.0	60.9
8	8	8.1	73.7	2	8.7	78.3	4	11.8	52.9	1	25.0	75.0	1	6.25	56.3	2	8.7	69.6
9	6	6.1	79.8	1	4.3	82.6	2	5.9	58.8	0	0.0	75.0	0	0.0	56.3	0	0.0	69.6
10	4	4.0	83.8	0	0.0	82.6	1	2.9	61.8	0	0.0	75.0	0	0.0	56.3	2	8.7	78.3
11	2	2.0	85.9	0	0.0	82.6	1	2.9	64.7	0	0.0	75.0	0	0.0	56.3	0.0	0.0	78.3
12	4	4.0	89.9	1	4.3	87.0	2	5.9	70.6	0	0.0	75.0	1	6.25	62.5	1	4.3	82.6
13	0	0.0	89.9	2	8.7	95.7	2	5.9	76.5	0	0.0	75.0	0	0.0	62.5	0	0.0	82.6
14	0	0.0	89.9	1	4.3	100.0	0	0	76.5	0	0.0	75.0	0	0.0	62.5	0	0.0	82.6
15	1	1.0	90.9	0	0.0	100.0	1	2.9	79.4	0	0.0	75.0	1	6.25	68.8	1	4.3	87.0
16	1	1.0	91.9	0	0.0	100.0	2	5.9	85.3	0	0.0	75.0	1	6.25	75.0	1	4.3	91.3
17	1	1.0	92.9	0	0.0	100.0	1	2.9	88.2	1	25.0	100.0	2	12.5	87.5	0	0.0	91.3
18	1	1.0	93.9	0	0.0	100.0	0.0	0.0	88.2	0	0.0	100.0	0	0.0	87.5	0	0.0	91.3
19	1	1.0	94.9	0	0.0	100.0	1	2.9	91.2	0	0.0	100.0	1	6.25	93.75	0	0.0	91.3
20	1	1.0	96.0	0	0.0	100.0	0.0	0.0	91.2	0	0.0	100.0	1	6.25	100.0	0	0.0	91.3
21	1	1.0	97.0	0	0.0	100.0	0.0	0.0	91.2	0	0.0	100.0	0	0.0	100.0	1	4.3	95.7
22	0	0.0	97.0	0	0.0	100.0	1	2.9	94.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
23	0	0.0	97.0	0	0.0	100.0	0.0	0.0	94.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
24	1	1.0	98.0	0	0.0	100.0	0.0	0.0	94.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
25	0	0.0	98.0	0	0.0	100.0	0.0	0.0	94.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
26	0	0.0	98.0	0	0.0	100.0	0.0	0.0	94.1	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	95.7

UTI – urinary tract infections; LRTIs – lower respiratory tract infections; SWI – surgical wound infections; BSIs – bloodstream infections

Table 7.8 continued: The day HAIs presented by site of infection

Day HAI presented	UTI			LRTIs			SWI			BSIs			Skin infections			Infections at other sites		
	No	% of UTIS	Cum %	No	% of LRTIs	Cum %	No	% of SWIs	Cum %	No	% of BSIs	Cum %	No	% of skin	Cum %	No	%	Cum %
27	0	0.0	98.0	0	0.0	100.0	0	0.0	94.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
28	0	0.0	98.0	0	0.0	100.0	1	2.9	97.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
29	0	0.0	98.0	0	0.0	100.0	0	0.0	97.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
30	0	0.0	98.0	0	0.0	100.0	0	0.0	97.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
31	0	0.0	98.0	0	0.0	100.0	0	0.0	97.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
32	0	0.0	98.0	0	0.0	100.0	0	0.0	97.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
33	0	0.0	98.0	0	0.0	100.0	0	0.0	97.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
34	0	0.0	98.0	0	0.0	100.0	0	0.0	97.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
35	0	0.0	98.0	0	0.0	100.0	0	0.0	97.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
36	0	0.0	98.0	0	0.0	100.0	0	0.0	97.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
37	0	0.0	98.0	0	0.0	100.0	0	0.0	97.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
38	0	0.0	98.0	0	0.0	100.0	0	0.0	97.1	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
39	1	1.0	99.0	0	0.0	100.0	1	2.9	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
40-44	00	0.0	99.0	0	0.0	100.0	0.	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	96.7
45	1	1.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
46	1	1.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
47	1	1.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
48	1	1.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
49	1	1.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	95.7
50	1	1.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	1	4.3	100.0
Total	**99**		**100.0**	**24**		**100.0**	**34**		**100.0**	**4**		**100.0**	**16**		**100.0**	**23**		**100.0**

UTI – urinary tract infections; LRTIs – lower respiratory tract infections; SWI – surgical wound infections; BSIs – bloodstream infections

7.7 The incidence of UTIs and identification of risk factors

7.7.1 The incidence of UTIs

Of the 2469 patients involved in this study, 100 patients acquired and presented with a UTI during the in-patient period: an incidence rate of 4.1% (95% CI: 3.3 to 4.9), with 13 patients presenting with an infection at one or more additional sites. Of these 13 patients, in eight cases the UTI was the primary infection. The incidence density was 5.7(95% CI: 4.7, 7.0) UTIs per 1000 patient days at risk, and 17.4 utis/1000 catheter days at risk.

Table 7.9 shows how the incidence of UTIs varies with selected patient characteristics. The characteristics included in this analysis included both intrinsic and extrinsic risk factors for hospital acquired UTIs identified from the literature and for which data were available (see section 2.8.3 for a discussion of risk factors for UTIs).

The incidence of UTIs was found to be significantly higher in women ($p=<0.001$) and varied with admission specialty ($p<0.001$), being highest in patients admitted to the gynaecology and obstetric specialties. The incidence of UTI was also found to vary significantly with discharge diagnosis, being highest in patients with a primary discharge diagnosis classified as 'Diseases of the genitourinary system', and was considerably higher in patients who had a catheter in situ prior to their infection. Urinary tract infection rates were 2.3 times higher in patients who had a catheter inserted compared to patients who did not have a catheter inserted. Finally, the incidence of UTI was found to be significantly higher in patients who had an operation and in those patients who received antibiotics prior to the infection, compared to those who did not, a factor which suggests that administration of antibiotics is a marker for another risk factor. That is prophylactic antibiotics are administered to patients thought to be at greater risk of acquiring an infection than those not given prophylactic antibiotics. With respect to the other variables included in this analysis, whilst the incidence of UTI was found to vary with age group, admission type and number of co-morbidities, the observed variation was not found to be statistically significant at the 5% level.

Table 7.9: The incidence of UTIs in surgical patients

Patient characteristic	n	UTI		IR (%) (95% CI)	P value
		No	Yes		
Sex					
Male	1003	985	18	1.8 (1.1 , 2.8)	<0.001
Female	1466	1384	82	5.6 (4.5 , 6.9)	
Age group					
18 –34	514	498	16	3.1 (1.8 , 5.0)	0.203
35-54	673	646	27	4.0 (2.7 , 5.9)	
55-74	951	914	37	3.9 (2.8 , 5.3)	
75+	331	311	20	6.0 (3.7 , 9.0)	
Admission type					
Elective	1629	1563	66	5.2 (4.0 , 6.6)	0.826
Emergency	840	807	34	4.0 (2.8 , 5.6)	
Specialty					
General surgery	884	869	15	1.7 (1.0 , 2.8)	<0.001
Orthopaedics	501	488	13	2.6 (1.4 , 4.4)	
Urology	472	455	18	3.8 (2.3 , 6.0)	
Gynaecology	386	344	41	10.6 (7.7 , 14.1)	
Obstetrics	226	213	13	5.8 (3.1 , 9.6)	
Discharge diagnosis group					
Infectious & parasitic disease	13	12	1	7.7 (0.2 , 36.0)	0.005
Neoplasms	357	341	16	4.5 (2.6 , 7.2)	
Endocrine, nutritional and metabolic diseases and immunity disorders	24	24	0	0.0 (0.0 , 14.2)	
Diseases of blood & blood forming organs	3	3	0	0.0 (0.0 , 70.8)	
Diseases of the nervous system & sense organs	2	2	0	0.0 0.0 , 84.2)	
Diseases of the circulatory system	150	146	4	2.7 (0.9 , 7.1)	
Diseases of the respiratory system	6	6	0	0.0 (0.0 , 45.9)	
Diseases of the digestive system	418	410	8	1.9 (0.8 , 3.7)	
Diseases of the genitourinary system	569	530	39	6.9 (4.9 , 9.3)	
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	254	239	15	5.9 (3.3 , 9.6)	
Diseases of the skin & subcutaneous tissue	31	31	0	0.0 (0.0 , 11.2)	
Diseases of the musculoskletal system & connective tissue	309	305	4	1.3 (0.4 , 3.3)	
Injury & poisoning	187	178	9	4.8 (2.4 , 8.9)	
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	146	142	4	2.7 (0.8 , 7.1)	
Number of co-morbidities					
None	1641	1578	63	3.8 (3.0 , 5.0)	0.862
One	579	553	26	4.5 (3.0 , 6.5)	
Two or more	249	238	11	4.4 (2.2 , 7.8)	
Antibiotics prior to UTI – any route					
No	972	944	28	2.9 (2.1 , 4.4)	0.04
Yes	1496	1425	71	4.7 (3.7 , 6.0)	
Antibiotics prior to UTI – IV/IM					
No	1210	1171	39	3.2 (2.3 , 4.4)	0.083
Yes	1258	1198	60	4.8 (3.7 , 6.1)	
Catheter present prior to UTI					
No	1757	1714	43	2.4 (1.9 , 3.4)	<0.001
Yes	711	655	56	7.9 (6.0 , 10.1)	
Operation*					
No	428	421	7	1.6 (0.6 , 3.4)	0.002
Yes	2041	1948	93	4.6 (3.7 , 5.6)	

UTI – urinary tract infection; IR – incidence rate * In the absence of data on day of operation for all 2041 patients who had an operative procedure the assumption was made that patients acquired their UTI after their first operative procedure. Note: With the exception of the antibiotic and catheter variables this analysis is based on all 2469 patients. The analysis examining how UTI rates

7.7.2 Independent risk factors for UTIs

In order to assess which factors were independently associated with an increased risk of acquiring a UTI, a logistic regression analysis was carried out. The analysis included all the variables listed in Table 7.9 with the exception of primary discharge diagnosis group, which was omitted from this analysis. The confidence intervals for the odds ratios of acquiring a UTI for the different primary discharge diagnosis group were very wide and as such the inclusion of this variable had little value. Table 7.10 presents the results of the single variable analysis, and Table 7.11 the results of the multivariable analysis.

It can be seen from Table 7.11 that after controlling for a range of factors the presence of a urinary catheter at some point prior to the infection and female sex were associated with the greatest increases in risk. The odds of acquiring a UTI were 2.6:1 in catheterised patients compared to non-catheterised patients and 2.8:1 in females compared to male patients. The odds of acquiring a UTI were also found to increase with increasing age category, and varied significantly with admission specialty. The odds of acquiring a UTI were higher for gynaecology and obstetric patients, compared to patients in the other specialty groups. The odds of acquiring a UTI were also greater in patients who had one or more co-morbidities. However there was no evidence that the odds increased with increasing number of co-morbidities. The odds of acquiring a UTI were higher for emergency patients, and were similar in patients who had antibiotics prior to a UTI and in those who had not, although the upper confidence intervals suggest that in some case patients who received prophylactic antibiotics were at greater risk of acquiring a UTI. This outcome suggests that the administration of prophylactic antibiotics is perhaps a maker for another risk factor not included in this model.

Table 7.10:The odds of acquiring a UTI key patient characteristics (single variable analysis)

Patient characteristic		UTI		Odds ratios (95% CI)	P value
	n	No	Yes		
Sex					
Male	1003	985	18	1.00	<0.0001
Female	1466	1384	82	3.24 (1.9 , 5.4)	
Age group					
18 –34	514	498	16	1.00	0.2331
35-54	673	646	27	1.30 (0.7 , 2.4)	
55-74	951	914	37	1.26 (0.7 , 2.4)	
75+	331	311	20	2.00 (1.0 , 3.9)	
Admission type					
Elective	1629	1563	66	1.00	0.8233
Emergency	840	807	34	0.95 (0.6 , 1.5)	
Specialty					
General surgery	884	869	15	1.00	<0.0001
Orthopaedics	501	488	13	1.54 (0.7 , 3.3)	
Urology	472	454	18	2.16 (1.1 , 4.4)	
Gynaecology	386	345	41	7.07 (3.9 , 12.9)	
Obstetrics	226	213	13	3.54 (1.7 , 7.5)	
Number of co-morbidities					
None	1641	1579	63	1.00	0.8634
One	579	553	26	1.11 (0.7 , 1.8)	
Two or more	249	238	11	1.16 (0.6 , 2.2)	
Diabetes listed as a co morbidity					
No	2378	2283	95	1.0	0.4977
Yes	91	86	5	1.4 (0.6 , 3.5)	
Antibiotics pre UTI – any route					
No	972	944	28	1.00	0.0266
Yes	1496	1425	71	1.62 (1.1 , 2.3)	
Antibiotics pre UTI – IV/IM					
No	1210	1171	39	1.00	
Yes	1258	1198	60	1.47 (1.0 , 2.2)	0.0636
Catheter present prior to UTI					
No	1757	1714	43	1.00	<0.0001
Yes	711	655	56	3.41 (2.3 , 5.1)	
Operation					
No	428	421	7	1.00	0.002
Yes	2041	1948	93	2.9 (1.3 , 6.2)	

UTI – urinary tract infection, CI – Confidence interval

Note: The analysis limited to 2468 patients for whom complete data sets were available

Table 7.11: The odds of acquiring a UTI by selected factors after controlling for all other factors listed (multivariable analysis).

Variable	Odds Ratio (95% CIs)	Sig of Log likelihood ratio
Sex		
Male	1.0	0.0027
Female	2.8 (1.4 , 5.6)	
Age group		
18-34	1.0	0.0154
35-54	1.8 (0.8 , 3.9)	
55-74	2.6 (1.1 , 6.0)	
75+	4.2 (1.7 , 10.4)	
Admission type		
Elective	1.0	0.0132
Emergency	2.0 (1.2 3 ,.5)	
Specialty		
General surgery	1.0	<0.0001
Orthopaedics	1.2 (0.5 , 2.7)	
Urology	1.9 (0.8 , 4.3)	
Gynaecology	5.2 (2.6 , 10.6)	
Obstetrics	3.1 (1.1 , 8.5)	
Number of co-morbidities		
None	1.0	
One	1.2 (0.7 , 2.0)	0.8292
Two or more	1.2 (0.5 , 2.5)	
Diabetes listed as a co-morbidity		
No	1.0	0.5242
Yes	1.4 (0.5 , 4.0)	
Antibiotics (any route) administered pre NUTI)		
No	1.0	0.8362
Yes	1.1 (0.5 , 2.3)	
Antibiotics (IV/IM) administered pre NUTI		
No	1.0	0.9205
Yes	1.0 (0.5 , 2.0)	
Catheter present prior to UTI		
No	1.0	<0.0001
Yes	2.6 (1.6 , 4.1)	
Operation		
No	1.0	0.0191
Yes	2.7 (1.1 , 6.5)	

CI – Confidence interval

Note: The analysis limited to 2468 patients for whom complete data sets were available

7.8 Incidence of SWIs and the identification of risk factors

7.8.1 Overall incidence of SWIs

Of the 2469 patients recruited into the study 44 presented with a SWI with 40 (1.6%, 95% CI: 1.2, 2.2) acquiring and presenting with a SWI during their admission to hospital. Twelve patients acquired one or more infections at other sites as well. The incidence density was 2.3 (95% CI: 1.6, 3.1) SWIs per 1000 patient days at risk.

Table 7.12 shows how the incidence varied with key patient characteristics. There was little variation in the incidence of SWI by the factors listed in Table 7.12.

7.8.2 The incidence of SWIs occurring in patients who had one or more operative procedures.

Of the 2469 patients recruited into the study 2041 had one or more operative procedures. Of these 2041 patients, 38 acquired a SWI: an incidence rate of 1.9% (95% CI: 1.3, 2.5). Table 7.13 shows how the incidence varied with selected patient characteristics. As with the analysis that included all patients, there was little variation in the incidence of SWIs with the patient characteristics included in the analysis.

7.8.3 Independent risk factors for SWI

In order to assess which factors were independently associated with an increased risk of acquiring a SWI, a logistic regression analysis was carried out. Since SWIs by definition can only occur in patients who had one or more operations, the analysis was limited to patients who had one or more operative procedures (n=2041). Table 7.14 presents the results of the single variable analysis, and Table 7.15 the results of the multivariable analysis. The analysis included all the variables listed in these tables.

There was little variation in the odds of acquiring a SWI with the factors included in the analysis. The only significant variation was with wound drain status. Patients who had one or more wound drains in place were 2.2 (95% CI: 1.0, 5.0) times more likely to acquire a SWI than those who did not.

Table 7.12: The incidence of SWIs in surgical patients

	n	SWI		IR (%) (95% CI)	P value
		No	Yes		
Sex					
Male	1003	989	14	1.4 (0.8 , 3.3)	0.465
Female	1466	1440	26	1.8 (1.2 , 2.6)	
Age group					
18-34	514	508	6	1.2 (0.4 , 2.5)	0.236
35-54	673	666	7	1.0 (0.4 , 2.1)	
55-74	951	932	19	2.0 (1.2 , 3.1)	
75+	331	323	8	2.4 (1.0 , 4.7)	
Specialty					
General surgery	884	868	16	1.8 (1.0 , 2.9)	0.162
Orthopaedics	501	489	12	2.4 (1.2 , 4.1)	
Urology	472	470	2	0.4 (0.1 , 1.5)	
Gynaecology	386	379	7	1.8 (0.7 , 3.7)	
Obstetrics	226	223	3	1.3 (0.3 , 3.8)	
Admission type					
Elective	1629	1604	25	1.5 (1.0 , 2.3)	0.555
Emergency	840	825	15	1.8 (1.0 , 2.9)	
Diagnosis group					
Infectious & parasitic disease	13	13	0	0.0 (0.0 , 24.7)	0.239
Neoplasms	357	350	7	2 (0.8 , 4.0)	
Endocrine, nutritional & metabolic diseases & immunity disorders	24	23	1	4.2 (0.1 , 21.1)	
Diseases of blood & blood forming organs	3	3	0	0.00 (0.0 , 70.8)	
Diseases of the nervous system & sense organs	2	2	0	0.0 (0.0 , 84.2)	
Diseases of the circulatory system	150	147	3	2 (0.4 , 5.7)	
Diseases of the respiratory system	6	6	0	0 (0.0 , 45.9)	
Diseases of the digestive system	418	414	4	1.0 (0.3 , 2.4)	
Diseases of the genitourinary system	569	563	6	1.1 (0.4 , 2.3)	
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	254	251	3	1.2 (0.2 , 3.4)	
Diseases of the skin & subcutaneous tissue	31	30	1	3.2 (0.1 , 16.7)	
Diseases of the musculoskletal system & connective tissue	309	305	4	1.3 (0.4 , 3.3)	
Injury & poisoning	187	178	9	4.8 (2.2 , 8.9)	
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	146	144	2	1.4 (0.2 , 4.9)	
Co-morbidities					
None	1642	1622	20	1.2 (0.7 , 1.9)	0.083
One	578	564	14	2.4 (1.3 , 4.0)	
Two or more	249	243	6	2.4 (0.9 , 5.2)	
Antibiotics (any route) administered pre SWI					
No	968	956	12	1.2 (0.6 , 2.2)	0.188
Yes	1501	1473	28	1.9 (1.2 , 2.7)	
Antibiotics (IV/IM) administered pre SWI					
No	1213	1199	14	1.2 (0.6 , 1.9)	0.105
Yes	1256	1230	26	2.1 (1.4 , 3.1)	

SWI – surgical wound infections, IR – incidence rate, CI – Confidence interval

Table 7.13:The incidence of SWI occurring in patients who had one or more operative procedures

Patient characteristic		SWI		IR (%) (95% CI)	P value
	n	No	Yes		
Sex					
Male	815	799	16	2.0 (1.1 , 3.2)	0.7823
Female	1226	1204	22	1.8 (1.1 , 2.7)	
Age group					
18-34	416	410	6	1.4 (0.5 , 3.1)	0.1665
35-54	570	564	6	1.1 (0.4 , 2.3)	
55-74	787	769	18	2.3 (1.4 , 3.6)	
75+	268	260	8	3.0 (1.3 , 5.8)	
Specialty					
General surgery	682	666	16	2.3 (1.3 , 3.8)	0.3083
Orthopaedics	433	422	11	2.5 (1.3 , 4.5)	
Urology	373	370	3	0.8 (0.2 , 2.3)	
Gynaecology	327	322	5	1.5 (0.5 , 3.5)	
Obstetrics	226	223	3	1.3 (0.3 , 3.8)	
Admission type					
Elective	1559	1536	23	1.5 (0.9 , 2.2)	0.0202
Emergency	482	467	15	3.1 (1.8 , 5.1)	
Diagnosis group					
Infectious & parasitic disease	3	3	0	0.0 (0.0 , 70.8)	0.328
Neoplasms	322	315	7	2.2 (0.9 , 4.3)	
Endocrine, nutritional & metabolic diseases & immunity disorders	24	23	1	4.2 (0.1 , 21.1)	
Diseases of blood & blood forming organs	1	1	0	0.0 (0.0 , 97.5)	
Diseases of the nervous system & sense organs	0	0	0	—	
Diseases of the circulatory system	131	128	3	2.3 (0.5 , 6.5)	
Diseases of the respiratory system	5	5	0	0.0 (0.0 , 52.2)	
Diseases of the digestive system	327	323	4	1.2 (0.3 , 3.1)	
Diseases of the genitourinary system	493	428	5	1.0 (0.3 , 2.4)	
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	241	238	3	1.2 (0.3 , 3.6)	
Diseases of the skin & subcutaneous tissue	25	24	1	4.0 (0.1 , 20.4)	
Diseases of the musculoskletal system & connective tissue	287	282	5	1.7 (0.6 , 4.0)	
Injury & poisoning	142	135	7	4.9 (2.0 , 9.9)	
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	40	38	2	5.0 (0.6 , 16.9)	
Co-morbidities					
None	1396	1376	20	1.4 (0.9 , 2.2)	0.0998
One	452	440	12	2.7 (1.4 , 4.6)	
Two or more	193	187	6	3.1 (1.1 , 6.6)	
Diabetes listed as a co-morbidity					
No	1971	1935	36	1.8 (1.3 , 2.5)	0.8332
Yes	70	2	2	2.9 (0.3 , 9.9)	
Antibiotics (any route) administered pre SWI					
No	720	708	12	1.7 (0.9 , 2.9)	0.63012
Yes	1321	1295	26	2.0 (1.3 , 2.9)	

Table 7.14:The odds of acquiring a SWI by key patient characteristics (single variable analysis)

Patient characteristic	n	SWI		Odds Ratio (95% CI)	P value
		No	Yes		
Sex					
Male	815	799	16	1.0	0.8973
Female	1226	1204	22	1.0 (0.5 , 2.1)	
Age group					
18-34	416	410	6	1.0	0.2789
35-54	570	564	6	0.7 (0.2 , 2.3)	
55-74	787	769	18	1.5 (0.6 , 3.9)	
75+	268	260	8	1.8 (0.6 , 5.5)	
Specialty					
General surgery	682	666	16	1.0	0.1514
Orthopaedics	433	422	11	1.0 (0.4 , 2.2)	
Urology	373	370	3	0.2 (0.1 , 1.0)	
Gynaecology	327	322	5	0.6 (0.2 , 1.8)	
Obstetrics	226	223	3	0.6 (0.2 , 1.9)	
Admission type					
Elective	1559	1536	23	1.0	0.0896
Emergency	482	467	15	1.9 (0.9 , 3.7)	
Co-morbidities					
None	1396	1376	20	1.0	0.0659
One	452	440	12	2.1 (1.0 , 4.4)	
Two or more	193	187	6	2.5 (1.0 , 6.3)	
Diabetes listed as a co-morbidity					
No	1971	1935	36	1.0	0.5147
Yes	70	2	2	1.7 (0.4 , 7.1)	
Antibiotics (any route) administered pre SWI					
No	720	708	12	1.0	0.2682
Yes	1321	1295	26	1.5 (0.7 , 3.1)	
Antibiotics (IV/IM) administered pre SWI					
No	904	891	13	1.0	0.0885
Yes	1137	1112	25	1.8 (0.9 , 3.7)	
Wound drain prior to SWI					
No	1921	1894	28	1.0	0.0071
Yes	548	539	12	2.5 (1.3 , 4.9)	

SWI – surgical wound infections

Table 7.15:The odds of acquiring a SWI by key patient characteristics (multi-variable analysis)

Patient characteristic	n	SWI		Odds Ratio (95% CI)	P value
		No	Yes		
Sex					
Male	815	799	16	1.0	0.6812
Female	1226	1204	22	0.8 (0.4 , 1.9)	
Age group					
18-34	416	410	6	1.0	0.3978
35-54	570	564	6	0.8 (0.2 , 2.8)	
55-74	787	769	18	1.7 (0.5 , 5.3)	
75+	268	260	8	1.9 (0.5 , 6.6)	
Specialty					
General surgery	682	666	16	1.0	0.3536
Orthopaedics	433	422	11	0.6 (0.3 , 1.5)	
Urology	373	370	3	0.3 (0.1 , 1.4)	
Gynaecology	327	322	5	1.2 (0.4 , 4.0)	
Obstetrics	226	223	3	0.7 (0.1 , 3.5)	
Admission type					
Elective	1559	1536	23	1.0	0.1043
Emergency	482	467	15	1.9 (0.9 , 4.1)	
Co-morbidities					
None	1396	1376	20	1.0	0.2693
One	452	440	12	1.9 (0.8 , 4.1)	
Two or more	193	187	6	1.8 (0.6 , 5.1)	
Diabetes listed as a co-morbidity					
No	1971	1935	36	1.0	0.820
Yes	70	2	2	0.8 (0.2 , 3.9)	
Antibiotics (any route) administered pre SWI					
No	720	708	12	1.0	0.5136
Yes	1321	1295	26	0.5 (0.1 , 4.3)	
Antibiotics (IV/IM) administered pre SWI					
No	904	891	13	1.0	0.3396
Yes	1137	1112	25	2.4 (0.3 , 18.6)	
Wound drain prior to SWI					
No	1921	1894	28	1.0	0.0501
Yes	548	539	12	2.2 (1.0 , 5.0)	

SWI – surgical wound infections, CI – Confidence interval

7.9 The incidence of LRTIs and identification of independent risk factors

7.9.1 The incidence of LRTIs

Of the 2469 patients involved in this study 23 (0.9%: 95% CI: 0.6, 1.4) acquired and presented with a LRTI during the in-patient period. The incidence density was 1.3 (95%CI: 0.8,1.9) per 1000 days at risk. Table 7.16 shows how the incidence of LRTI varied with selected patient characteristics. The results indicated that the incidence was higher in males than females; increased with increasing age; was highest in surgical patients; was higher in emergency as compared to elective admissions; was highest in patients whose primary discharge diagnosis was classified as a neoplasm; increased with increasing number of co-morbidities; was higher in patients who had diabetes listed as a co-morbidity, patients who had surgery, patients with a naso-gastric tube and/or endotracheal or tracheostomy tube in place prior to the onset of infection, and higher in patients who received antibiotics prior to infection. However, the only significant variation was with age group, number of co-morbidities, presence of a naso-gastric and/or endotracheal or tracheostomy tube prior to the onset of infection and increasing age.

7.9.2 Independent risk factors for LRTIs

To assess which factors were independently associated with an increased risk of acquiring a LRTI, a logistic regression analysis was conducted. Tables 7.18 and 7.19 present the results of the single and multivariable logistic regression analysis. In the single variable analysis significant variation was observed with respect to age, the number of co-morbidities, and presence of an NG tube and/or endotracheal or tracheostomy tube. However, the results of the multivariable analysis indicated that the only significant variation in the odds of acquiring a LRTI was with the presence or absence of an endotracheal or tracheostomy tube. The odds of acquiring a LRTI were found to be 44.4 (95% CI: 6.6, 288.0) times higher in patients who had an endotracheal or tracheostomy tube than those who did not.

Table 7.16: The incidence of LRTIs in surgical patients

Patient characteristic	n	LRTI		IR% (95% CI)	P value
		No	Yes		
Sex					
Male	1003	990	13	1.3 (0.7 , 2.2)	0.119
Female	1466	1456	10	0.7 (0.3 , 1.3)	
Age group					
18-34	514	513	1	0.2 (0.0 , 1.1)	0.024
35-54	673	669	4	0.6 (0.2 , 1.5)	
55-74	951	940	11	1.2 (0.6 , 2.1)	
75+	331	324	7	2.1 (0.9 , 4.3)	
Specialty					
General surgery	884	871	13	1.5 (0.8 , 2.5)	0.299
Orthopaedics	501	497	4	0.8 (0.2 , 2.0)	
Urology	472	470	2	0.4 (0.1 , 1.5)	
Gynaecology	386	383	3	0.8 (0.2 , 2.3)	
Obstetrics	226	225	1	0.4 (0.0 , 2.4)	
Admission type					
Elective	1629	1616	13	0.8 (0.4 , 1.4)	0.336
Emergency	840	830	10	1.2 (0.6 , 2.2)	
Diagnosis group					
Infectious & parasitic disease	13	13	0	0.0 (0.0 , 24.7)	0.0387
Neoplasms	357	351	6	1.7 (0.6 , 3.6)	
Endocrine, nutritional & metabolic diseases & immunity disorders	24	23	1	4.2 (0.1 , 21.9)	
Diseases of blood & blood forming organs	3	3	0	0.0 (0.0 , 70.8)	
Diseases of the nervous system & sense organs	2	2	0	0.0 (0.0 , 45.9)	
Diseases of the circulatory system	150	149	1	0.7 (0.0 , 3.7)	
Diseases of the respiratory system	6	5	1	16.7 (0.4 , 64.1)	
Diseases of the digestive system	418	414	4	1.0 (0.3 , 2.4)	
Diseases of the genitourinary system	569	566	3	0.5 (0.1 , 1.5)	
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	254	253	1	0.4 (0.0 , 2.2)	
Diseases of the skin & subcutaneous tissue	31	31	0	0.0 (0.0 , 11.2)	
Diseases of the musculoskletal system & connective tissue	309	307	2	0.6 (0.1 , 2.3)	
Injury & poisoning	187	185	2	1.1 (0.1 , 3.8)	
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	146	144	2	1.4 0.2 , 4.9)	
Co-morbidities					
None	1642	1632	10	0.6 (0.3 , 1.1)	<0.001
One	578	573	5	0.9 (0.3 , 2.0)	
Two or more	249	241	8	3.2 (1.4 , 6.2)	
Diabetes listed as a co-morbidity					
No	2378	2357	21	0.9 (0.6 , 1.3)	0.214
Yes	91	89	2	2.2 (0.3 , 7.7)	
NG tube present pre- LRTI					
No	2376	2360	16	0.7 (0.4 , 1.1)	<0.001
Yes	93	86	7	7.5 (3.1 , 14.9	
Tracheostomy or ET tube pre LRTI					
No	2449	2433	16	0.7 (0.4 , 1.1)	<0.001
Yes	20	13	7	35.0 (15.4 , 59.2)	
Antibiotics pre LRTI – any route					
No	1002	995	7	0.7 (0.3 , 1.4)	0.467
Yes	1467	1451	16	1.1 (0.6 , 1.8)	
Antibiotics pre LRTI – intravenous route only					
No	1228	1220	8	0.7 (0.3 , 1.5)	0.228
Yes	1241	1226	15	1.2 (0.7 , 1.9)	
Operation					
No	428	426	2	0.5 (0.1 , 1.7)	0.096
Yes	2041	2020	21	1.0 (0.6 , 1.6)	

Table 7.17: The odds of acquiring a LRTI (single variable analysis)

	n	LRTI		Odds Ratio (95% CI)	P value
		No	Yes		
Sex					
Male	1003	990	13	1.0	0.1231
Female	1466	1456	10	0.5 (0.2 , 1.2)	
Age group					
18-34	514	513	1	1.0	0.0223
35-54	673	669	4	3.1 (0.3 , 37.5)	
55-74	951	940	11	6.0 (0.8 , 46.6)	
75+	331	324	7	11.1 (1.4 , 90.5)	
Specialty					
General surgery	884	871	13	1.0	0.2919
Orthopaedics	501	497	4	0.5 (0.2 , 1.7)	
Urology	472	470	2	0.3 (0.1 , 1.3)	
Gynaecology	386	383	3	0.5 (0.1 , 1.9)	
Obstetrics	226	225	1	0.3 (0.0 , 2.3)	
Admission type					
Elective	1629	1616	13	1.0	0.3450
Emergency	840	830	10	1.5 (0.7 , 3.4)	
Co-morbidities					
None	1642	1632	10	1.0	0.0047
One	578	573	5	1.4 (0.5 , 4.2)	
Two or more	249	241	8	5.4 (2.1 , 13.9)	
Diabetes listed as a co-morbidity					
No	2378	2357	21	1.0	0.2723
Yes	91	89	2	2.5 (0.6 , 10.9)	
NG tube pre LRTI					
No	2376	2360	16	1.0	<0.001
Yes	93	86	7	12.0 (4.8 , 29.9)	
Endo-tracheal or tracheostomy tube pre LRTI					
No				1.0	<0.001
Yes	2449	2433	16	81.9 (28.9 , 232.1)	
Antibiotics pre LRTI – any route					
No	1002	995	7	1	0.3110
Yes	1467	1451	16	1.6 (0.6 , 3.8)	
Antibiotics pre LRTI – intravenous route only					
No	1228	1220	8	1.0	0.1463
Yes	1241	1226	15	1.9 (0.8 , 4.4)	
Operation					
No	428	426	2	1.0	0.2323
Yes	2041	2020	21	2.2 (0.5 , 9.5)	

LRTI – lower respiratory tract infection; CI – confidence interval

Table 7.18: The odds of acquiring a LRTI (multi-variable analysis)

	n	LRTI		Odds Ratio (95% CI)	P value
		No	Yes		
Sex					
Male	1003	990	13	1.0	0.1690
Female	1466	1456	10	0.5 (0.2 , 1.4)	
Age group					
18-34	514	513	1	1.0	0.0613
35-54	673	669	4	3.9 (0.3 , 47.6)	
55-74	951	940	11	5.1 (0.4 , 69.3)	
75+	331	324	7	14.3 (1.0 , 201.6)	
Specialty					
General surgery	884	871	13	1.0	0.4609
Orthopaedics	501	497	4	0.8 (0.2 , 2.9)	
Urology	472	470	2	0.4 (0.1 , 2.1)	
Gynaecology	386	383	3	2.6 (0.5 , 13.2)	
Obstetrics	226	225	1	2.9 (0.2 , 48.1)	
Admission type					
Elective	1629	1616	13	1.0	0.5128
Emergency	840	830	10	1.4 (0.5 , 4.4)	
Co-morbidities					
None	1642	1632	10	1.0	0.0737
One	578	573	5	0.9 (0.3 , 3.4)	
Two or more	249	241	8	3.7 (1.1 , 12.0)	
Diabetes listed as a co morbidity					
No	2378	2357	21	1.0	
Yes	91	89	2	0.5 (0.1 , 3.5)	
NG tube pre LRTI					
No	2376	2360	16	1.0	0.8084
Yes	93	86	7	1.3 (0.2 , 8.3)	
Endotracheal or tracheostomy tube pre LRTI					
No				1.0	<0.001
Yes	2449	2433	16	44.4 (6.6 , 288.0)	
Antibiotics pre LRTI– any route					
No	1002	995	7	1.0	0.6549
Yes	1467	1451	16	0.6 (0.1 , 5.4)	
Antibiotics pre LRTI – intravenous route only					
No	1228	1220	8	1.0	0.6358
Yes	1241	1226	15	1.3 (0.1 , 10.9)	
Operation					
No	428	426	2	1.0	0.4022
Yes	2041	2020	21	2.0 (0.4 , 10.8)	

7.10 Conclusion

In this chapter the results of the analysis that examined the incidence of HAI and how it varied with selected patient characteristics have been presented. Of the 2469 patients included in this analysis 7.5% acquired and presented with an infection during their hospital stay. UTIs were the most frequent type of infections, followed by surgical wound and lower respiratory tract infections. Independent risk factors for these infections varied with site. The following two chapters consider the impact these infections had on resource use and costs incurred by the hospital sector. Chapter 8 presents the results of the analysis that examined the impact these infections had on costs incurred by the hospital sector and Chapter 9 the results of the analysis that examined the impact these infections had on length of hospital stay.

CHAPTER 8

THE IMPACT OF HAIS ON HOSPITAL IN-PATIENT COSTS: RESULTS

8.1 Introduction

The results of the analysis that assessed the impact that hospital acquired infections (HAIs) occurring in surgical patients, had on hospital costs incurred during the patients' hospital stay are presented in this chapter. The results of the single variable analysis that explored how costs varied with HAI status and a range of other patient characteristics are presented first (section 8.2). This is followed by the results of the multivariable analysis and the results of the analysis that looked at the distribution of the costs incurred by infected and uninfected patients (sections 8.3 and 8.4). Further details of the methods used can be found in section 5.5 of Chapter 5.

8.2 Results of the single variable analysis

Table 8.1 presents the results of the single variable analysis that assessed how hospital costs varied with selected patient characteristics. The mean, standard deviation, median, 25th and 75th percentiles and minimum and maximum values are presented. The median figure in all cases is lower than the mean costs and the standard deviations, in most cases, are larger than the mean costs, indicating that the hospital cost data are highly skewed in the positive direction.

On average inpatient costs amounted to £1,845 per patient. Costs were found to vary with patient characteristics: women, on average, incurred higher hospital costs than men; hospital costs increased with increasing age group after the age of 35; hospital costs varied with admission specialty, with obstetric patients on average incurring the highest costs; mean hospital costs also varied with diagnosis group; increased with increasing number of co-morbidities; were higher for emergency admissions compared to elective admissions and were higher in infected compared to uninfected patients. Infected patients on

average incurred costs that were 2.5 times those incurred by uninfected patients.

The significance of the variation in costs incurred by patients of differing sex, age groups, admission specialty, diagnosis groups, number of co-morbidities and HAI status was assessed using the non-parametric Mann-Whitney and Kruskal-Wallis tests and found to be highly significant in all cases ($p=<0.001$). Because of the large samples the significance of the observed variation in the mean costs incurred by patients with differing patient characteristics was also tested using the parametric t test. Similar results were obtained. The variation in arithmetic means was found to be highly significant ($p=<0.001$).

Table 8.1: Hospital costs incurred during the in-patient hospital stay by key patient characteristics

Patient characteristic	n	The cost of hospital in-patient care (£)						
		Mean	Median	SD	Percentile		Minimum	Maximum
					25th	75th		
Sex								
Male	1003	1635	1143	1891	750	1847	247	21269
Female	1466	1989	1773	2074	993	2243	247	39179
Age group								
18-34	514	1788	1588	1655	870	2115	247	15937
35 – 54	673	1646	1391	2043	800	1948	255	39179
55-74	951	1824	1379	1871	860	2201	247	21269
75+	331	2398	1800	2636	939	2722	292	21881
Specialty								
General surgery	884	1628	939	2475	671	1534	247	23688
Orthopaedics	501	2422	2157	2403	1262	2711	356	39179
Urology	472	1404	1159	1085	853	1573	292	12901
Gynaecology	386	1732	1815	726	1481	2043	334	5412
Obstetrics	226	2528	2121	1480	1872	2535	922	12072
Admission type								
Elective	1629	1667	1430	1460	750	1847	247	23688
Emergency	840	2191	1510	2748	993	2243	297	39179
Discharge diagnosis group								
Infectious & parasitic diseases	13	872	845	452	514	1114	396	2074
Neoplasms	357	1992	1393	2201	952	2169	276	21158
Endocrine, nutritional & metabolic diseases & immunity disorders	24	1484	1278	764	1155	1484	594	4389
Diseases of blood & blood forming organs	3	992	922	688	342	1713	342	1713
Diseases of the nervous system & sense organs	2	712	712	461	386	1038	386	1039
Diseases of the circulatory system	150	1719	753	3514	597	1065	247	21881
Diseases of the respiratory system	6	5596	2098	6230	1488	12038	1086	15937
Diseases of the digestive system	418	1346	933	1781	670	1373	288	23688
Diseases of the genitourinary system	569	1568	1587	936	963	1938	292	11253
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	254	2405	2104	1473	1857	2392	504	12072
Diseases of the skin & subcutaneous tissue	31	1389	828	2384	611	1173	452	13839
Diseases of the musculoskletal system & connective tissue	309	2215	2216	1184	1268	2681	356	8520
Injury & Poisoning	187	2634	1941	3356	1258	2781	431	39179
Symptoms, signs & ill-defined conditions; mental disorders & congenital abnormalities	146	1479	844	2018	663	1517	299	15731
Co-morbidities								
None	1642	1699	1407	1763	833	2089	247	39179
One	578	1946	1499	2197	851	2181	288	23688
Two	173	2315	1718	2338	1029	2579	398	15937
Three or more	76	3158	1916	3509	936	3628	254	18987
HAI								
No	2276	1656	1360	1420	815	2073	247	23688
Yes	193	4081	2430	4745	1824	4014	668	39179

It should be noted the effects of HAI confound the results presented in Table 8.1. As reported in Chapter 7 the incidence of HAI varied with patient characteristics, and as such the variation in costs incurred by patients with differing patient characteristics can in part be attributed to the differing incidence of HAI in the sub-groups examined and the impact that the infections had on costs. The results presented in Table 8.2 show how hospital costs varied with both infection status (infected/uninfected) and selected patient characteristics. The mean costs for both infected and uninfected patients and how these vary with selected patient characteristics are presented, together with the ratios of the costs for infected compared to uninfected patients and the additional costs incurred by infected patients.

The mean costs for infected patients were higher than uninfected patients for all the patient characteristics examined. On average, amongst infected patients, costs were higher in males than females, increased with increasing age, were highest for surgical patients, varied with primary diagnosis group and increased with increasing number of co-morbidities.

Table 8.3 shows how mean costs varied with type of infection. The mean costs varied with site of infection and for all sites, infected patients, on average, incurred higher costs than uninfected patients. The observed variation was found to be significant ($p=<0.0001$). Of those patients who acquired an infection in hospital, patients who acquired a urinary tract infection (UTI), on average, incurred the lowest costs and patients who acquired more than one infection, on average, incurred the highest hospital costs. The results of the analysis which considered how costs varied with each type of infection and selected characteristics are presented in Appendix 12. The results indicated that whilst, on average, hospital costs were higher in infected than uninfected patients for all the selected characteristics, the pattern of variation varied with type of infection. However, it should be noted that the number of patients in some of the infection groups was small and the results therefore cannot be safely generalized.

Table 8.2: Mean in-patient hospital costs by HAI status and key patient characteristics

Patient characteristic	Mean cost of hospital in-patient care (£)				Ratio of costs (95% CI)	Extra in-patient costs/ patient (£) (95% CI)
	No HAI		HAI			
	Mean	n	Mean	n		
Sex	(a)		(b)		(b/a)	(b-a)
Male	1439	946	4889	57	3.4 (2.5, 4.2)	3450 (2991, 3909)
Female	1810	1330	3742	136	2.1 (1.6, 2.5)	1932 (1579, 2285)
Age group						
18 –34	1672	485	3741	29	2.2 (1.4, 3.0)	2069 (1473, 2665)
35-54	1509	627	3512	46	2.3 (1.2, 3.5)	2003 (1408, 2597)
55-74	1636	870	3837	81	2.3 (1.8, 2.9)	2201 (1798, 2604)
75+	1997	294	5587	37	2.8 (1.8, 3.8)	3590 (2772, 4408)
Specialty						
General surgery	1338	829	6011	55	4.5 (3.3, 5.7)	4673 (4071, 5275)
Orthopaedics	2157	462	5558	39	2.6 (1.6, 3.6)	3401 (2672, 4130)
Urology	1316	445	2846	27	2.2 (1.4, 2.9)	1530 1130, 1929)
Gynaecology	1682	336	2073	50	1.2 (1.1, 1.4)	391 (178, 604)
Obstetrics	2508	204	2715	22	1.1 (0.9, 1.2)	207 (-448, 863)
Admission type						
Elective	1569	1519	3013	757	1.9 (1.5, 2.3)	1443 (1169, 1717)
Emergency	1828	110	5496	83	3.0 (2.3, 3.7)	3667 (3095, 4240)
Discharge diagnosis group						
Infectious & parasitic diseases	867	12	940	1	1.1 (0.8, 1.4)	73 (-1007, 1154)
Neoplasms	1714	329	5263	28	3.1 (1.9, 4.2)	3549 (2780, 4318)
Endocrine, nutritional & metabolic diseases & immunity disorders	1360	20	2102	4	1.5 (0.4, 2.7)	742 (-82, 1566)
Diseases of blood & blood forming organs	992	3	-	0	— ——	— —
Diseases of the nervous system & sense organs	712	2	-	0	— ——	— —
Diseases of the circulatory system	1134	142	12111	8	10.7 (5.1, 6.2)	10977 (9180, 12774)
Diseases of the respiratory system	1726	4	13338	2	7.7 (4.1, 11.4)	11612 (7071, 16152)
Diseases of the digestive system	1249	396	3107	22	2.5 (1.6, 3.3)	1859 (1112, 2605)
Diseases of the genitourinary system	1501	519	2259	50	1.5 (1.3, 1.7)	758 (493, 1023)
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	2382	230	2616	24	1.1 (0.9, 1.3)	234 (-389, 856)
Diseases of the skin & subcutaneous tissue	951	28	5483	3	5.8 (-3.0, 14.5)	4532 (2060, 7005)
Diseases of the musculoskletal system & connective tissue	2176	296	3106	13	1.4 (1.4, 10.1)	930 (1783, 7262)
Injury & Poisoning	2136	160	5586	27	2.6 (1.2, 4.0)	3450 (2163, 4736)
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	1189	135	5050	11	4.2 (1.6, 6.9)	3861 (2779, 4943)
Number of co-morbidities						
None	1582	1532	3332	110	2.1 (1.5, 2.7)	1750 (1419, 2081)
One	1723	528	4304	50	2.5 (1.8, 3.2)	2582 (1979, 3185)
Two	2012	216	6236	33	3.1 (2.3, 3.9)	4224 (3350, 5097

Table 8.3: Hospital in-patient costs by type of HAI

Type of HAI	n	Cost of hospital in-patient care (£)						
		Mean	Median	SD	Percentile		Minimum	Maximum
					25th	75th		
No HAI	2276	1656	1360	1420	815	2073	247	23688
UTI only	88	2856	2322	2665	1753	2718	668	19781
SWI only	32	4315	3032	3310	1849	4988	1254	12362
LRTI only	15	3182	2366	2308	1675	3652	714	9762
BSI only	3	8953	8263	6665	2660	.	2660	15937
Skin only	13	3603	2898	1954	2348	5603	953	7247
Other only*	18	3410	2138	3731	1655	3138	782	13839
Multiple	24	9774	5161	9315	2340	16253	916	39179

UTI – urinary tract infection, SWI – surgical wound infection, LRTI – lower respiratory tract infection, BSI – bloodstream infection

*single site infections at sites not classified elsewhere i.e. infections at a sites other than the urinary tract, surgical wounds, lower respiratory tract, skin, or bloodstream

8.3 Results of the multivariable regression analysis

This section presents the results of the multivariable regression analysis. For the purposes of this analysis it was assumed that the dependent variable 'hospital costs' had a Gamma distribution. Based on this assumption a generalised linear model of the impact of HAI on hospital costs after controlling for age, sex, specialty, admission type and number of co-morbidities was constructed using a maximum likelihood approach and a) an identity link and b) a log link. Details of the methods employed can be found in section 5.5 of Chapter 5

As detailed in Chapter 5, the identity link assumes additive effects and enables estimates of the mean additional costs incurred by infected patients to be deduced directly from the model, whereas using a log link assumes multiplicative or proportional effects and thus gives estimates of the ratio of costs incurred by infected and uninfected patients. to be taken directly from the model. The results of the generalised linear model that used an identity link are presented in Section 8.3.1 and the results of the model that used a loglink are presented in section 8.3.2.

8.3.1 Results of the generalised linear model that used an identity link

8.3.1.1 Estimates of the cost of HAI

The results of the generalised linear model, which assumed that the dependent variable 'hospital cost' had a Gamma distribution and used a maximum likelihood approach and an identity link, are presented in Table 8.4.

Table 8.4: Results of the generalised linear model which assessed the impact of HAI on hospital costs using an identity link

		Coef	95% CI		P value
			Low	High	
Constant		759.02	607.02	911.01	
Sex	Males	REF			0.0055
	Females	213.21	79.36	347.06	
Age Group	18-34	REF			<0.0001
	35 – 54	278.98	128.41	429.56	
	55-74	467.86	318.03	617.68	
	75+	650.33	424.31	876.34	
Specialty	General surgery	REF			<0.0001
	Orthopaedics	741.46	549.64	933.27	
	Urology	17.20	-126.85	161.25	
	Gynaecology	336.82	153.37	520.28	
	Obstetrics	1253.73	935.94	1571.51	
Type of admission	Elective	REF			0.0118
	Emergency	179.01	51.48	306.53	
Number of co-morbidities	None	REF			0.0203
	One	90.02	-47.44	227.48	
	Two or more	351.26	101.80	600.73	
HAI status	No HAI	REF			<0.0001
	HAI	2254.21	1738.361	2770.05	

REF – reference category

The results presented in Table 8.4 indicate that on average HAIs cost the hospital sector an additional £2,254 (95% CI: £1,738, £2,770) per case.

8.3.1.2 *Testing for interactions*

The above model presents a relatively simple model of the impact of HAI on hospital costs. A more detailed model was fitted allowing for the effects of interactions. All two-way interactions between HAI and the other independent variables were assessed. All interaction terms were entered into the model and the least significant term was subsequently removed and the model re-run. This process was repeated until only significant interaction terms remained ($p=<0.05$). Significant interactions were found between HAI and specialty.

8.3.1.3 *Specialty specific estimates of the impact of HAI on hospital costs*

Specialty specific estimates of the additional costs incurred by infected patients derived from the generalised linear model, which incorporated an interaction term for HAI and specialty, are presented in Table 8.5 together with the mean costs incurred by infected and uninfected patients.

Table 8.5: Specialty specific estimates of the additional costs incurred by infected patients

	Mean in-patient costs (£)		Mean additional costs (£) (model estimate: 95% CIs)*
	No HAI	HAI	
General surgery	1338	6011	4673 (4368:2992, 5744)
Orthopaedics	2157	5558	3401 (3357:1821, 4894)
Urology	1316	2846	1530 (1474:534, 2414)
Gynaecology	1682	2073	391 (375:-145, 895)
Obstetrics	2508	2715	207 (185:-841, 1211)

*Estimates were derived from the generalised linear model assuming that the outcome variable 'hospital costs' has a Gamma distribution and using a maximum likelihood approach and identity link. The model controlled for the effects of age, sex, admission specialty, admission type, and number of co-morbidities and incorporated an interaction term for HAI and specialty

With the exception of HAIs occurring in gynaecology and obstetric patients the estimated additional costs incurred by infected patients were significantly higher than those incurred by uninfected patients from the same specialty (p=<0.01). Infections occurring in surgical patients on average cost the hospital sector an estimated £4,368 (95% CI: £2,992, £5,744) per case, in orthopaedic patients an estimated £3,357 (95% CI: £1,821, £4,894) per case; in urology patients an estimated £1,474 (95% CI: £534, £2,414) per case; in gynaecology patients an estimated £375 (95% CI: -£145, £895) per case and in obstetric patients an estimated £185 (95% CI: - £841, £1,211) per case.

8.3.1.4 Site specific estimates of the impact of HAI on hospital costs

The preceding tables have presented the results of the analysis that assessed the average costs of HAI. Table 8.6 presents the results of the analysis that assessed the costs of specific types of infection. As before estimates were derived using generalised linear modelling statistical techniques. The model assessed the impact of different types of infection on hospital costs after controlling for age, sex, specialty, admission type and number of co-morbidities. The impact of the following types of infection was assessed: urinary tract, lower respiratory tract, surgical wound, bloodstream, an infection at a site not classified elsewhere, and multiple infections. Since the preceding model identified an interaction between HAI and specialty, the model also included this interaction term. However, the interaction term was not found to be significant in this model and as such was dropped from the analysis. The model identified highly significant variation in costs incurred by patients with different types of infection. However, at the level of each category of infection the significance of the variation in costs incurred compared to uninfected patients varied. Bloodstream and skin infections costs were not found to be significantly different from the costs incurred by uninfected patients, whereas the cost of all other infections were (p=<0.01). However, the number of patients in some of the subgroups were small and thus the study sample is unlikely to have had sufficient power to identify a significant difference in costs in these patients if present.

Table 8.6: Estimates of the additional costs incurred by infected patients by site of infection

Infection status	Mean costs (£)	Mean additional costs incurred by infected patients (£) (model estimate: 95% CIs)
No HAI	1656	
UTI	2856	1200 (944: 441, 1446)
LRTI	4315	2659 (2672: 753, 4592)
SWI	3182	1526 (1497: 548, 2447)
BSI	8953	7297 (6953: -1652, 15558)
Skin	3603	1947 (1567: -110, 3245)
Other single site infection	3410	1754 (1671: 279, 3064)
Multiple infections	9774	8118 (7930: 4551, 11310)

UTI – urinary tract infection, LRTI – lower respiratory tract infection, SWI – surgical wound infection, BSI – bloodstream infection, CI – confidence interval

The results presented in Table 8.6 indicate that UTIs were the least expensive infections, and multiple infections the most expensive. On average UTIs were estimated to cost the health service an additional £944 (95% CI: £441, £1,446) per case, whereas multiple infections were estimated to cost the health service an additional £7,930 (95% CI: £4,551, £11,310) per case.

8.3.2 Results of the generalised linear model that used a loglink

8.3.2.1 Estimates of the ratio of costs incurred by infected and uninfected patients

The results of the generalised linear model which assumed that the dependent variable 'hospital cost' had a Gamma distribution and used a maximum likelihood approach and a log link are presented in Table 8.7.

Table 8.7: Results of the generalised linear model which assessed the impact of HAI on hospital costs using a log link

		Model estimates of the ratio of costs Coef (exp)	95% CI		P value
			Low	High	
Sex	Males	REF			0.0468
	Females	1.1	1.0	1.2	
Age Group	18-34	REF			<0.0001
	35 – 54	1.2	1.1	1.4	
	55-74	1.4	1.2	1.5	
	75+	1.6	1.4	1.8	
Specialty	General surgery	REF			<0.0001
	Orthopaedics	1.5	1.4	1.7	
	Urology	1.0	0.9	1.1	
	Gynaecology	1.2	1.1	1.4	
	Obstetrics	2.0	1.7	2.3	
Type of admission	Elective	REF			0.002
	Emergency	1.1	1.1	1.2	
Number of co-morbidities	None	REF			
	One	1.1	1.0	1.2	0.006
	Two or more	1.2	1.1	1.4	
HAI status	No HAI	REF			<0.0001
	HAI	2.3	2.0	2.6	

REF – reference category

The results presented in Table 8.7 indicate that on average hospital costs incurred by infected patients are 2.3 (95% CI: 2.0, 2.6) times that of uninfected patients.

8.3.2.2 Testing for interactions

As with the model that used an identity link, the above model presents a relatively simple model of the impact of HAI on hospital costs. A more detailed model was fitted allowing for the effects of interactions. All two-way interactions between HAI and the other independent variables were assessed. All interaction terms were entered into the model and the least significant term was subsequently removed and the model re-run. This process was repeated until only significant interaction terms remained ($p=<0.05$). Significant interactions were found between HAI and specialty.

8.3.2.3 Specialty specific estimates of the impact of HAI on hospital costs

Specialty specific estimates of the ratio of costs incurred by infected and uninfected patients derived from the generalised model allowing for possible interactions between HAI and admission specialty are presented in Table 8.8.

Table 8.8: Specialty specific estimates of the ratio of costs incurred by infected and uninfected patients

	Mean in-patient costs (£)		Ratio of costs incurred by infected and uninfected patients (model estimate: 95% CIs)*
	No HAI	HAI	
General surgery	1338	6011	5.5 (3.9: 3.0,4.9)
Orthopaedics	2157	5558	3.6 (2.4: 1.8, 3.3)
Urology	1316	2846	3.2 (2.1: 1.5, 2.9)
Gynaecology	1682	2073	2.2 (1.2: 0.9, 1.6)
Obstetrics	2508	2715	2.1 (1.1: 0.7,1.6)

*Estimates were derived from the generalised linear model which assessed the impact of HAI on hospital costs allowing for the effects of age, sex, admission type, admission specialty, and number of co-morbidities and allowing for possible interactions between HAI and admission specialty and which used a log link.

The results presented in Table 8.8 show that infected general surgical patients on average incurred the greatest proportional increases in cost. The results of the generalised linear model indicated that, on average, infections occurring in general surgical patients were estimated to increase hospital costs by a factor of 3.9 (95% CI: 3.0, 4.9). The model estimates of the ratio of costs were similar for orthopaedic and urology patients. On average, infected patients incurred costs that were twice those of uninfected patients. In contrast estimates of the impact of infections occurring in gynaecology and obstetric patients on hospital costs indicated that infections occurring in these patients resulted in a slight increase in costs. On average costs were 1.2 (95% CI: 0.9, 1.6) times higher in infected gynaecology patients than uninfected patients from the same specialty and 1.1 (95% CI: 03.7, 1.6) in obstetric patients compared to uninfected patients from the same specialty. However, it should be noted that the confidence intervals for these estimates included zero and as such there was some uncertainty as to whether HAIs occurring in these patients increased costs.

8.3.2.4 *Site specific estimates of the impact of HAI on hospital costs*

The preceding tables have presented the results of the analysis that assessed the ratio of costs incurred by patients with one or more HAIs at any site compared to the costs incurred by uninfected patients. Table 8.9 presents the results of the analysis that assessed the costs of specific types of infection. As before, the generalised linear model assumed a Gamma distribution and used a log link to assess the impact of different types of infection on hospital costs after controlling for age, sex, specialty, admission type and number of co-morbidities. Since the preceding model identified an interaction between HAI and specialty, the model also included this interaction term. However, the interaction term was not found to be highly significant in this model (p = 0.054) and as such was dropped from the analysis. The results presented in Table 8.10 are limited to the estimates of the ratio of costs incurred by patients acquiring specific types of infection compared to uninfected patients derived from the generalised linear model.

Table 8.9: Estimates of the ratio of costs incurred by infected compared to uninfected patients by site of infection

Infection status	Mean costs (£)	Ratio of costs incurred by infected compared to uninfected patients (model estimate: 95% CIs)*
No HAI	1656	
UTI	2856	1.7 (1.6: 1.3, 1.9)
LRTI	4315	2.6 (2.8: 1.8, 4.3)
SWI	3182	1.9 (1.9: 1.4, 2.6)
BSI	8953	5.4 (6.0: 2.2, 16.2)
Skin	3603	2.2 (2.0: 1.2, 3.2)
Other single site infection	3410	2.1 (2.0: 1.3, 2.9)
Multiple infections	9774	5.9 (5.8: 3.9, 7.9)

UTI – urinary tract infection, LRTI – lower respiratory tract infection, SWI – surgical wound infection, BSI – bloodstream infection, CI – confidence interval

* Estimates were derived from the generalised linear model which assessed the impact of HAI on hospital costs allowing for the effects of age, sex, admission type, admission specialty, and number of co-morbidities and allowing for possible interactions between HAI and admission specialty and which used a log link.

The results presented in Table 8.9 show that UTIs were estimated to have the lowest impact on hospital costs. Patients who acquired a UTI were estimated to incur hospital costs that were 1.6 (95% CI: 1.3, 1.9) times those incurred by uninfected patients. Surgical wound infections, skin infections and infections at sites not classified elsewhere were all estimated to increase hospital costs by a factor of about 2, whereas bloodstream infections were estimated to increase hospital costs by a factor of 6.0 and multiple infections by a factor 5.8

8.4 The distribution of hospital costs incurred by infected and uninfected patients

This section presents the results of the analysis that explored how hospital costs and the distribution of these costs differed between infected and uninfected patients. Table 8.10 presents the mean costs for infected and uninfected patients, the additional costs incurred by infected compared to uninfected patients, and the contribution each category of costs makes to the overall additional costs incurred by infected patients. Model estimates of the additional costs incurred by infected patients allowing for the effects of age, sex, admission specialty, admission type and number of co-morbidities, are also presented in the table. It should be noted that whilst a significant interaction between HAI and admission specialty was identified, for the purposes of this analysis this has been ignored and the average impact of HAI across all specialties on the various cost categories assessed.

Table 8.9: The distribution of hospital costs incurred by infected and uninfected patients

	Mean hospital costs (£)					
	No HAI	HAI (any site(s))				% contribution to additional costs
	n=2276	n=193	Ratio of costs	Additional costs (£) (model estimate: 95% CI)		
Hospital overheads	392.89	855.46	2.18	462.57	(411.94: 284.35, 539.34)	19.07
Directorate management	47.55	101.69	2.14	54.13	(44.34: 29.72, 58.95)	2.23
Capital charges	208.20	439.36	2.11	231.16	(203.66: 139.95, 267.37)	9.53
Medical time	150.72	334.42	2.22	183.69	(148.12: 99.75, 196.48)	7.57
Nursing care	338.11	1319.18	3.90	981.07	(912.36: 645.95, 1178.78)	40.46
Paramedics and specialist nurses	11.71	52.42	4.48	40.71	*	1.68
Physiotherapy	16.01	60.06	3.75	44.05	*	1.82
Consumables used for specific procedures	11.06	80.77	7.30	69.71	(62.95: 16.35, 109.55)	2.87
Surgical interventions	335.63	437.73	1.30	102.10	(134.16: 81.97, 186.35)	4.21
Antimicrobials	11.80	48.60	4.12	36.80	(27.54: 6.49, 48.58)	1.52
Non-antimicrobial drugs	32.92	119.31	3.62	86.39	(73.37: 13.24, 138.51)	3.56
Microbiology tests	5.74	26.99	4.70	21.24	*	0.88
Other pathology tests	54.59	110.75	2.03	56.16	*	2.32
Endoscopies	1.71	2.22	1.30	0.51	*	0.02
Radiology	33.35	85.38	2.56	52.02	*	2.15
Other tests	3.53	6.29	1.78	2.76	*	0.11
Total costs	1655.51	4080.60	2.46	2425.09	(2254: 1738, 2770)	100.00

*The distribution of the values of these components of costs were too extreme for standard modelling procedures

The results present in Table 8.10 show that in all cost categories the costs incurred by infected patients were higher than in uninfected patients. The cost categories that accounted for the majority of the additional costs were those linked to time in hospital. The costs of hospital overheads, directorate management, capital charges and medical time were all assigned to individual patients on the basis of their length of hospital stay. When these categories are taken together it follows that 38.4% of the additional costs were directly linked to time in hospital. This combined category represents the second largest contributor to additional costs, the largest being nursing care accounting for 40.46% of the additional costs incurred. The cost of antimircrobials and microbiology tests were over four times higher in infected than uninfected patients. However, anti-microbial costs only accounted for 1.52% of the additional costs incurred by infected patients and the cost of microbiology tests just 0.88% of the additional costs incurred.

The results of the analysis that examined the distribution of additional costs incurred by infected patients for each type of infection are presented in Appendix 13. For all cost categories, costs incurred by infected patients were higher than uninfected patients and in most cases costs linked to LOS represented a substantial proportion of the additional costs incurred by infected cases. The exception was BSIs, where costs directly linked to time in hospital accounted for just 1.13% of the additional costs incurred. The cost of nursing care represented the greatest proportion of additional costs accounting for 59.98%, and drugs other than anti-microbials the second largest contributor accounting for 13.49%. The cost of drugs other than antibiotics was 30.9 times that of uninfected patients. However, it should be noted that there were only three patients who acquired a BSI and no other infection.

Antibiotic costs varied with site of infection. Overall, patients who acquired an infection in hospital on average incurred antibiotic costs amounting to £48.60 per patient. However, antibiotic costs ranged from a low mean cost of £13.41 per patient with a UTI to a relatively high average cost of £141.06 per case for patients with multiple infections.

Similarly, when looking at the costs of microbiology tests, a cost category which is directory relevant to the detection and management of infections, whereas on average infected patients incurred costs amounting to £26.90 (4.7 times the costs incurred by uninfected patients); the cost varied with site, from a low of £11.92 per patient with a skin infection to a relatively high average cost of £78.25 for patients with multiple infections.

8.5 Conclusion

This chapter has presented the result of the analysis that assessed the impact of HAIs on hospital costs. These results, to be discussed in detail in Chapter 11, clearly demonstrate the substantial burden HAIs place on the hospital sector. It is also clear from the distribution analysis, that whilst mean costs incurred by infected patients are in all categories higher than the mean costs incurred by uninfected patients, a large proportion of the additional costs incurred are linked to a prolonged hospital stay. This impact on length of hospital stay is explored in more detail in the next chapter.

CHAPTER 9

THE IMPACT OF HAIS ON LENGTH OF HOSPITAL STAY: RESULTS

9.1 Introduction

The results of the analysis that assessed the impact of HAIs on length of hospital stay (LOS) are presented in this chapter. Section 9.2 presents the results of the single variable analysis and sections 9.3 - 9.5 the results of the multivariable analysis. Further details of the methods used can be found in section 5.5 of Chapter 5.

9.2 Results of the single variable analysis

Table 9.1 presents the results of the single variable analysis which assessed how LOS varied with key patient characteristics. The mean, standard deviation, median, 25th and 75th percentiles and minimum and maximum values are presented. The median LOS in almost all cases is lower than the mean LOS and the standard deviations in most cases are larger than the mean LOS indicating that the LOS data is highly skewed.

The mean length of hospital stay was 7.4 days. On average women remained in hospital longer than men; LOS increased with increasing age; orthopaedic patients on average remained in hospital longer than patients in the other specialty groups; LOS varied with diagnosis group; was longer in emergency compared to elective admissions; increased with increasing number of co-morbidities, and was longer in infected than uninfected patients.

The significance of the variation in LOS by patients of differing sex, age group, admission specialty, admission type, number of co-morbidities and HAI status was first assessed using the non-parametric Mann-Whitney and Kruskal-Wallis tests. The observed variation was significant ($p=<0.001$). The variation in median LOS by all the factors listed in Table 9.1 was also found to be highly significant ($p=<0.001$).

The significance of the observed variation in the mean LOS was also tested using the parametric t test. Parametric tests are based on the assumption that the data for each group has an approximately normal distribution.[232] In this case it clearly was not; however, the t test is fairly robust to non-normality. The variation in arithmetic means was found to be highly significant (p=<0.001).

Table 9.2 presents the results of the analysis that explored in more detail how LOS stay varied with HAI status. The mean LOS for both infected and uninfected patients are presented and how this varies with selected patient characteristics, together with the ratios of the LOS for infected compared to uninfected patients and the number of additional days infected patients remained in hospital. The mean LOS for infected patients was higher than for uninfected patients for all the patient characteristics examined. On average infected males remained in hospital longer than females, the LOS amongst infected patients increased with increasing age, was highest for infected surgical patients, varied with primary diagnosis group and increased with increasing number of co morbidities.

Table 9.3 shows how the mean LOS varied with type of infection. The mean LOS varied with site of infection and for all sites was greater than uninfected patients. The observed variation was found to be significant (p=<0.0001). Of those patients who acquired an infection in hospital, patients who acquired a UTI, on average, had the shortest length of stay and patients who acquired more than one infection on average had the longest length of stay.

Further analysis examined how for each type of infection the length of stay varied with selected characteristics. The results are presented in Appendix 14. The results showed that whilst the length of hospital stay for all the selected characteristics was higher in infected than uninfected patients the pattern of variation varied with type of infection. However, it should be noted that the number of patients in some of the infection groups was small and as such the results cannot be safely generalized.

Table 9.1: Length of hospital stay by key patient characteristics

Patient characteristic	n	Length of hospital stay (days)						
		Mean	Median	SD	Percentile		Minimum	Maximum
					25th	75th		
Sex								
Male	1003	6.5	4	7.1	2.0	8.0	1	88
Female	1466	7.9	6	9.3	4.0	9.0	1	153
Age group								
18-34	514	6.4	5	8.6	3.0	6.0	1	124
35 – 54	673	5.9	5	5.1	3.0	7.0	1	78
55-74	951	7.6	5	7.6	3.0	9.0	1	88
75+	331	11.2	8	13.7	3.0	13.0	1	153
Specialty								
Surgery	884	6.5	4	9.9	2.0	7.0	1	153
Orthopaedics	501	11.3	9	10.1	5.0	13.0	1	97
Urology	472	5.6	4	6.3	3.0	6.0	1	88
Gynaecology	386	6.4	6	3.7	5.0	8.0	1	34
Obstetrics	226	7.5	6	5.5	5.0	8.0	1	45
Admission type								
Elective	1629	6.4	5	7.2	3.0	8.0	1	153
Emergency	840	9.2	6	10.4	4.0	10.0	1	97
Primary discharge diagnosis group								
Infectious and parasitic diseases	13	3.8	3	1.6	2.0	5.0	2	6
Neoplasms	357	7.5	5	7.6	3.0	9.0	1	68
Endocrine, nutritional and metabolic diseases and immunity disorders	24	5.2	5	2.4	4.0	6.0	1	13
Diseases of blood and blood forming organs	3	4.3	5	3.1	1.0	6.0	1	7
Diseases of the nervous system and sense organs	2	3.5	3.5	2.1	2.0	5.0	2	5
Diseases of the circulatory system	150	7.7	3	18.6	2.0	5.0	1	153
Diseases of the respiratory system	6	9.2	9.5	4.3	5.3	12.0	3	15
Diseases of the digestive system	418	5.3	3	5.4	2.0	6.0	1	51
Diseases of the genitourinary system	569	5.7	6	3.8	3.0	7.0	1	38
Complications of pregnancy, childbirth and puerperium & certain conditions originating in the perinatal period	254	7.4	6	5.6	5.0	7.0	1	45
Diseases of the skin and subcutaneous tissue	31	7.6	4	16.9	2.0	6.0	2	97
Diseases of the musculoskletal system and connective tissue	309	10.7	10	7.7	5.0	13.0	1	52
Injury and Poisoning	187	11.6	8	11.6	5.0	14.0	1	78
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	146	7.2	4	10.5	3.0	7.0	1	88
Co-morbidities								
None	1642	6.6	5	6.4	3.0	8.0	1	97
One	578	8.1	5	11.5	3.0	8.0	1	153
Two	173	10.3	7	11.1	3.5	12.0	1	75
Three or more	76	11.8	8	12.0	4.0	15.0	1	80
HAI								
No	2276	6.6	5	6.6	3.0	8.0	1	124
Yes	193	16.1	10	18.1	7.0	17.0	3	153

CI – confidence interval

Table 9.2: The mean length of stay by HAI status and key patient characteristics

Patient characteristic	Mean length of hospital stay (days)				Ratio of days (95% CI)	No. of additional days (95% CI)
	No HAI		HAI			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	5.9	946	17.1	57	2.9 (2.2 , 3.6)	2.9 (9.5 , 13.0)
Female	7.1	1330	15.6	136	2.2 (1.7 , 2.7)	2.2 (6.9 , 10.1)
Age group						
18 -34	6.0	485	12.6	29	2.1 (1.0 ,3.2)	2.1 (3.4 , 9.8)
35-54	5.5	627	11.1	46	2.0 (1.4 , 2.6)	2.0 (4.1 , 7.1)
55-74	6.8	870	15.6	81	2.3 (1.8 , 2.7)	2.3 (7.1 , 10.4)
75+	9.4	294	26.0	37	2.8 (2.0 , 3.5)	2.8 (12.3 , 21.0)
Specialty						
Surgery	5.4	829	22.8	55	4.2 (3.0 , 5.5)	4.2 (14.9 , 19.9)
Orthopaedics	10.3	462	22.9	39	2.2 (1.6 , 2.8)	2.2 (9.5 , 15.7)
Urology	5.1	445	14.0	27	2.7 (1.8 , 3.7)	2.7 (6.5 , 11.2)
Gynaecology	6.1	336	8.0	50	1.3 (1.1 , 1.5)	1.3 (0.7 , 2.9)
Obstetrics	7.5	204	8.3	22	1.1 (0.9 , 1.3)	1.1 (-1.6 , 3.3)
Admission type						
Elective	6.0	1519	12.4	110	2.1 (1.6 , 2.8)	2.1 (5.1 , 7.8)
Emergency	7.9	757	20.9	83	2.7 (2.1 , 3.2)	2.7 (10.9 , 15.2)
Primary discharge diagnosis group*						
Infectious and parasitic diseases	3.8	12	3.0	1	0.8* 0.8*	0.8* -0.8*
Neoplasms	6.7	329	17.2	28	2.6 (1.9 , 3.2)	2.6 (7.8 , 13.3)
Endocrine, nutritional and metabolic diseases and immunity disorders	4.9	20	7.0	4	1.4 (0.9 , 2.0)	1.4 (-0.4 , 4.7)
Diseases of blood and blood forming organs	4.3	3	0.0	0.0	— —	— —
Diseases of the nervous system and sense organs	3.5	2	0.0	0.0	— —	— —
Diseases of the circulatory system	5.0	142	55.9	8	11.2 (3.8 , 18.6)	11.2 (40.4 , 61.5)
Diseases of the respiratory system	7.0	4	13.5	2	1.9 (1.0 , 2.9)	1.9 (-0.6 , 13.6)
Diseases of the digestive system	4.9	396	12.2	22	2.5 (1.8 , 3.2)	2.5 (5.1 , 19.5)
Diseases of the genitourinary system	5.4	519	9.3	50	1.7 (1.4 , 2.1)	1.7 (2.9 , 5.0)
Complications of pregnancy, childbirth and puerperium & certain conditions originating in the perinatal period	7.3	230	8.1	24	1.1 (1.0 , 1.2)	1.1 (-5.4 , 7.1)
Diseases of the skin and subcutaneous tissue	4.5	28	37.0	3	8.2 (6.0 , 10.5)	8.2 (29.7 , 35.3)
Diseases of the musculoskletal system and connective tissue	10.5	296	16.2	13	1.5 (1.4 , 1.7)	1.5 (1.5 , 10.0)
Injury and Poisoning	9.9	160	22.0	27	2.2 2.2 (1.5 , 3.0)	2.2 (7.7 , 16.6)
Symptoms, signs and ill-defined conditions; mental disorders & congenital abnormalities	5.8	135	24.6	11	4.3 (1.4 , 7.1)	4.3 (13.1 , 24.6)
Number of co-morbidities						

Table 9.3: Length of hospital stay by infection status

Type of HAI		Length of hospital stay (days)						
	N	Mean	Median	SD	Percentile		Minimum	Maximum
					25th	75th		
No HAI	2276	6.6	5.0	6.6	3.0	8.0	1.0	124.0
UTI	88	11.5	8.0	10.0	6.0	12.8	3.0	56.0
SWI	32	14.6	11.0	10.8	9.0	17.0	3.0	45.0
LRTI	15	14.5	13.0	9.4	7.25	18.8	4.0	45.0
BSI	3	8.7	9.0	3.5	5.0	12	5.0	12.0
Skin infection	13	18.8	16.0	11.8	8.0	32	4.0	38.0
Other single site infection not classified elsewhere	18	20.0	8.0	27.4	6.0	21.3	4.0	97.0
Multiple infections	24	32.5	20.5	33.7	9.0	34.8	4.0	153.0

UTI – urinary tract infection, LRTI – lower respiratory tract infection, SWI – surgical wound infection, BSI – bloodstream infection

9.3 Results of the multivariable analysis

This section presents the results of the multivariable analysis. In this model the dependent variable 'LOS' was assumed to have a Gamma distribution and a generalised linear model of the impact of HAI on LOS after controlling for age, sex, specialty, admission type and number of co-morbidities was constructed using a maximum likelihood approach and a) an identity link and b) a log link. Details of the methods employed can be found in section 5.5 of Chapter 5.

As detailed in Chapter 5, and referred to in Chapter 8, the identity link assumes additive effects and consequently enables estimates of the mean additional costs incurred by infected patients to be taken directly from the model. In contrast the log link assumes multiplicative or proportional effects and as such gives estimates of the ratio of costs incurred by infected patients and uninfected patients. The results of the generalised linear model that used an identity link are presented in Section 9.3.1 and the results of the model that used a log link are presented in section 9.2.

9.3.1 Results of the generalised linear model that used an identity link

9.3.1.1 Estimates of the impact of HAI on length of hospital stay

Table 9.4 presents the results of the generalised linear model to assess the impact of HAI on LOS after controlling for the effects of age, sex, admission specialty, admission type and number of co-morbidities. The model assumed that the dependent variable 'hospital LOS' had a Gamma distribution and used a maximum likelihood approach and an identity link.

Table 9.4: Results of the generalised linear model which assessed the impact of HAI on length of hospital stay using an identity link

		Coef	95% CI		P value
			Low	High	
Constant		2.64	1.99	3.29	
Sex	Males	REF			0.0001
	Females	1.20	0.622	1.78	
Age Group	18-34	REF			<0.0001
	35 – 54	0.59	-0.64	1.23	
	55-74	1.72	1.045	2.40	
	75+	2.90	1.81	4.00	
Specialty	Surgery	REF			<0.0001
	Orthopaedics	4.34	3.37	5.31	
	Urology	0.10	-0.50	0.70	
	Gynaecology	0.98	0.21	1.76	
	Obstetrics	1.97	0.88	3.07	
Type of admission	Elective	REF			<0.0001
	Emergency	1.57	0.99	2.15	
Number of co-morbidities	None	REF			0.0007
	One	0.81	0.19	1.43	
	Two or more	1.64	0.51	2.78	
HAI status	No HAI	REF			<0.0001
	HAI	7.83	5.67	10.00	

REF – reference category

The results indicate that on average infected patients remain in hospital 7.83 (95% CI: 5.67 to 10.00) days longer than uninfected patients.

9.3.1.2 *Testing for interactions*

The above model presents a relatively simple model of the impact of HAI on LOS. A more detailed model was fitted allowing for the effects of interactions. All two-way interactions between HAI and the other independent variables were assessed. All interaction terms were entered into the model and the least significant term was subsequently removed and the model re-run. This process was repeated until only significant interaction terms remained ($p=<0.05$). Significant interactions were found between HAI and specialty ($p=<0.001$).

9.3.1.3 *Specialty specific estimates of the impact of HAI on length of hospital stay*

Table 9.5 presents the specialty specific estimates of the average number of additional days infected patients remained in hospital, derived from the generalised linear model that incorporated an interaction term for HAI and specialty, together with the mean LOS of infected and infected patients.

Table 9.5: Specialty specific estimates of the impact of HAI on length of hospital stay

	Mean LOS (days)		Number of extra days infected patients remained in hospital (model estimate 95% CIs)*
	No HAI	HAI	
Surgery	5.4	22.8	17.4 (15.26: 9.49, 21.03)
Orthopaedics	10.3	22.9	12.6 (11.73: 4.70, 18.75)
Urology	5.1	14	8.9 (7.88: 2.85, 12.93)
Gynaecology	6.1	8	1.9 (1.79: -0.43, 4.01)
Obstetrics	7.5	8.3	0.8 (0.60 -2.87, 4.07)

LOS = length of stay

*The model estimates were derived from a generalised linear model that used an identity link and controlled for age, sex, admission specialty, admission type, number of co-morbidities, and included an interaction term for HAI and specialty

The results presented in Tables 9.5 indicate that HAIs occurring in surgical patients had the greatest impact on LOS in terms of the number of extra days patients were estimated to remain in hospital as a result of acquiring and infection. On average HAIs occurring in surgical patients were estimated to prolong the in-patient stay by an additional 15.3 (95% CI: 9.5, 21.0) days. In contrast infections occurring in gynaecology patients were estimated to increase the patients LOS by just 1.8 days (95% CI: -.04, 4.0) days and in obstetric patients the presence of one or more HAIs was estimated to increase the LOS by just over half a day (0.6 days, 95% CI: -.3, 4.1). Estimates of the impact HAIs occurring in the other specialty groups had on LOS varied. HAIs occurring in orthopaedic patients were, on average, estimated to extend the in-patient stay by 11.7 (95% CI: 4.7, 18.8) days; and HAIs occurring in urology patients were estimated to extend the hospital stay by 7.9 (95% CI: 2.9, 12.9) days.

9.3.1.4 Site specific estimates of the impact of HAI on length of hospital stay

The preceding tables have presented the results of the analysis that assessed the average costs of HAI. Table 9.6 presents the results of the analysis that assessed the costs of specific types of infection. As before the generalised linear model assumed a Gamma distribution and used a maximum likelihood approach and identity link. The model assessed the impact of different types of infection on hospital LOS after controlling for age, sex, specialty, admission type and number of co-morbidities. The impact of the following types of infection were assessed: urinary tract, lower respiratory tract, surgical wound, bloodstream, infections at a site not classified elsewhere, and multiple infections. Since the preceding model identified an interaction between HAI and specialty, the model also included this interaction term. However, the interaction term was not found to be significant in this model and was dropped from the analysis. The results of this analysis are given in Table 9.6, together with the mean costs incurred by infected and uninfected patients by infection group.

Table 9.6: Estimates of the impact of specific types of HAI on length of hospital stay

Type of HAI	n	Mean	Number of additional days (model estimate: 95% CI)*
No HAI	2276	6.6	
UTI only	88	11.5	4.9 (3.27: 1.25, 5.28)
SWI only	32	14.6	8.0 (7.18: 2.34, 12.02)
BSI only	3	8.7	2.1 (2.21: -7.08, 11.49)
LRTI only	15	14.5	7.9 (8.01: 0.62,15.37)
Skin only	13	18.8	12.2 (9.85: 0.37, 19.33)
Other only	18	20.0	13.4 (11.59: 2.97, 20.21)
Multiple	24	32.5	25.9 (24.01: 11.84, 36.18)

CI – confidence interval

*Model estimates obtained from generalised linear modelling that controlled for the effects of age, sex, admission specialty, admission type, number of co-morbidities, and included a variable denoting type of infection.

The results presented in Table 9.6 indicate that on average multiple infections have the highest impact on LOS. Patients who acquired more than one infection in hospital were estimated to remain in hospital an estimated 24 (95% CI: 11.9, 36.2) extra days. In contrast BSIs were estimated to increase the in-patient stay by just 2.2 (95% CI: -7.1, 15.37) days. However, it should be noted that there were just three patients who acquired a BSI and no other infections, two of whom died in hospital. As evidenced by the CIs there was considerable uncertainty about this finding, and as such the results cannot be safely generalised. UTIs had the second lowest impact on LOS. On average UTIs were estimated to prolong the patients stay by 3.3 (95% CI: 1.3, 5.3) days. SWIs, LRTIs, skin infections and infections at other sites were estimated to increase the average LOS by 7 – 12 days, with the estimate of increase varying with site.

9.3.2 *Results of the generalised linear model that used a loglink*

9.3.2.1 *Estimates of the ratio of LOS incurred by infected and uninfected patients*

The results of the generalised linear model which assumed that the dependent variable 'hospital cost' had a Gamma distribution and used a maximum likelihood approach and a log link are presented in Table 9.7.

Table 9.7: Results of the generalised linear model which assessed the impact of HAI on length of hospital stay using a log link

		Model estimates of the ratio of LOS Coef (exp)	95% CI		P value
			Low	High	
Sex	Males	REF			0.0008
	Females	1.2	1.1	1.3	
Age Group	18-34	REF			<0.0001
	35 – 54	1.1	1.1	1.3	
	55-74	1.4	1.2	1.5	
	75+	1.6	1.4	1.9	
Specialty	General surgery	REF			<0.0001
	Orthopaedics	1.7	1.6	1.9	
	Urology	1.0	0.9	1.1	
	Gynaecology	1.2	1.0	1.3	
	Obstetrics	1.4	1.2	1.6	
Type of admission	Elective	REF			<0.0001
	Emergency	1.3	1.2	1.4	
Number of co-morbidities	None	REF			
	One	1.2	1.0	1.3	0.0001
	Two or more	1.3	1.1	1.5	
HAI status	No HAI	REF			<0.0001
	HAI	2.1	1.8	2.5	

REF – reference category

The results presented in Table 9.7 indicate that on average infected patients have a hospital LOS that is 2.1 (95% CI: 1.8, 2.5) times that of uninfected patients.

9.3.2.2 *Testing for interactions*

As with the model that used an identity link, the above model presents a relatively simple model of the impact of HAI on LOS. A more detailed model was fitted allowing for the effects of interactions. All two-way interactions between HAI and the other independent variables were assessed. All interaction terms were entered into the model and the least significant term was subsequently removed and the model re-run. This process was repeated until only significant terms remained ($p=<0.05$). Significant interactions were found between HAI and specialty.

9.3.2.3 *Specialty specific estimates of the impact of HAI on LOS*

Specialty specific estimates of the ratio of the LOS incurred by infected and uninfected patients derived from the generalised model allowing for possible interactions between HAI and admission specialty are presented in Table 9.8.

Table 9.8: Specialty specific estimates of the ratio of costs incurred by infected and uninfected patients

	Mean LOS (days)		Ratio of days (model estimate: 95% CIs)*	
	No HAI	HAI		
Surgery	5.4	22.8	4.22	(3.4: 2.6, 4.4)
Orthopaedics	10.3	22.9	2.22	(2.0: 1.4, 2.7)
Urology	5.1	14	2.75	(2.5: 1.7, 3.6)
Gynaecology	6.1	8	1.31	(1.3: 1.0, 1.7)
Obstetrics	7.5	8.3	1.11	(1.1: 0.7, 1.6)

CI – confidence interval

*Estimates were derived from the generalised linear model which assessed the impact of HAI on LOS allowing for the effects of age, sex, admission type, admission specialty, and number of co-morbidities and allowing for possible interactions between HAI and admission specialty and which used a log link.

The results presented in Table 9.8 show that infected general surgical patients on average incurred the greatest proportional increases in LOS. The results of the generalised linear model indicated that, on average, infections occurring in general surgical patients were estimated to increase the patients LOS by a

factor of 3.4 (95% CI: 2.6, 4.4). Infections occurring in urology patients were estimated to result in an average LOS that was 2.5 times that of uninfected patients from the same specialty, and infections occurring in orthopaedic patients were estimated to result in an average LOS that was twice as long as uninfected patients from the same specialty. HAIs occurring in gynaecology and obstetric patients were not estimated to have a substantial impact on LOS. Infections occurring in gynaecology patients were estimated to increase the LOS by a factor of 1.3, and infections occurring in obstetric patients were estimated to have a LOS that was just 1.1 times that of uninfected patients from the same specialty.

9.3.2.4 Site specific estimates of the impact of HAI on LOS

The preceding tables have presented the results of the analysis that assessed the average increase in LOS incurred by patients who acquired one or more infections in hospital. Table 9.9 presents the results of the analysis that assessed the impact of specific types of infection on LOS. As before the generalised linear model assumed a Gamma distribution and used a log link to assess the impact of different types of infection on hospital LOS after controlling for age, sex, specialty, admission type and number of co-morbidities. The impact of the following types of infection were assessed: urinary tract, lower respiratory tract, surgical wound, bloodstream, an infection at a site not classified elsewhere, and multiple infections. Since the preceding model identified an interaction between HAI and specialty, the model also included this interaction term. However, the interaction term was not found to be significant in this model ($p = 0.138$) and as such was dropped from the analysis.

Table 9.9: Estimates of the ratio of LOS incurred by infected patients compared to uninfected patients by site of infection

Type of HAI	n	Mean	Ratio of LOS (model estimate: 95% CI)*
No HAI	2276	6.6	
UTI only	88	11.5	1.7(1.5:1.13, .1.9)
SWI only	32	14.6	2.2(2.0: 1.5, 2.9)
BSI only	3	8.7	1.3(1.5: 0.5, 4.4)
LRTI only	15	14.5	2.2(2.3: 1.4, 3.8)
Skin only	13	16.8	2.6(2.5: 1.5, 4.2)
Other only	18	20.0	3.3(2.7: 1.7, 4.2)
Multiple	24	32.5	4.9(4.4: 2.9, 6.5)

UTI – urinary tract infection, LRTI – lower respiratory tract infection, SWI – surgical wound infection, BSI – bloodstream infection, CI – confidence interval

* Estimates were derived from the generalised linear model which assessed the impact of HAI on hospital LOS allowing for the effects of age, sex, admission type, admission specialty, and number of co-morbidities and allowing for possible interactions between HAI and admission specialty and which used a log link.

The results presented in Table 9.9 show that BSIs were estimated to have the lowest impact on LOS. Acquisition of a BSI was estimated, on average, to increase the LOS by a factor of 0.5. However, as noted in section 9.3.1 there were just three patients in this infection group, two of whom died as in-patients thus curtailing their length of hospital stay. The acquisition of a UTI was also estimated to increase the LOS by a factor of 0.5. SWIs, LRTIs, skin infections and infection at sites not classified elsewhere were estimated to result in a LOS that on average was twice that of uninfected patients, whereas multiple infections were estimated to result in a LOS that on average was 4.4 times that of uninfected patients.

9.4 Conclusion

In this chapter the results of the analysis that explored the impact of HAI on length of hospital stay were presented. Whilst the results of this analysis will be discussed in detail in Chapter 11, it is clear from the preceding sections that HAIs have a substantial impact on hospital length of stay. The following chapter will consider how the estimates of both the impact of HAI on LOS and also the impact on hospital cost can be used in models to assess the benefits of investment in prevention.

CHAPTER 10
THE POTENTIAL BENEFITS OF INVESTMENT IN INFECTION PREVENTION AND CONTROL

10.1 Introduction

The results of this study clearly demonstrate that hospital acquired infections (HAI) place a substantial burden on health care resources. This chapter will explore how the results of this analysis, and indeed estimates taken from other studies, can be used to assess the magnitude and distribution of the potential benefits of investment in infection control. Estimates of the gross benefits of investment in prevention and control activities and a framework for assessment of net benefits are presented.

10.2 The potential benefits of prevention

The estimates of the economic burden of HAIs derived in this study and presented in Chapters 8 and 9, may be considered to represent the gross benefits of prevention, as measured by costs avoided if an infection is prevented. The net benefits will depend on the cost and effectiveness of infection control practices.

10.3 The gross benefits of prevention

As indicated above the results of this analysis represent the gross benefits of prevention, as measured by the average costs that may be avoided if an infection is prevented. The magnitude of these gross benefits within a particular clinical setting will depend on both the number and types of infections prevented.

Estimates of the proportion of HAIs that are preventable vary. As mentioned in Chapter 1, perhaps the most widely quoted estimate of the proportion of infections that could be avoided through improvements in infection prevention and control is that derived as part of the SENIC study conducted in the US in

the mid 1970s and early 1980s. The study estimated that 30% of infections could be prevented.[11] It is not known how applicable this estimate is to the situation in NHS hospitals in England. The results of a recent National Audit Office survey of infection control teams indicated that many of the teams felt that this was an overestimate of the proportion that were preventable. Infection control teams were asked to estimate the proportion of HAIs they considered preventable. The estimates varied, ranging from a low estimate of 5% to over 35%. The bed weighted average was 15%.[3] Whilst it is acknowledged that this estimate is a subjective assessment of the proportion of HAIs that can be prevented, for the purpose of exploring the potential benefits of prevention, the more conservative estimate of 15% will be used to explore the potential gross benefits of prevention at the level of the study hospital and also at the national level.

10.3.1 Methods used to derive estimates of the potential gross benefits of a 15% reduction in infection rates

Estimates of the potential gross benefits of a 15% reduction in rates were derived from estimates of the number of patients acquiring one or more infections and the burden these infections imposed on the hospital sector. These latter estimates were derived from data on the observed incidence of HAIs presenting during the in-patient period; the estimated ratio of the hospital costs and LOS incurred by infected compared to uninfected patients obtained from the generalised linear modelling analysis; the mean hospital costs and mean LOS incurred by uninfected patients; and data on the number of adult admissions to the specialties covered in this study at a) the study hospital in 1994/5 and b) NHS hospitals throughout England in 1994/5.

Estimates of the number of patients acquiring one or more infections were derived by applying the observed incidence of HAI to the number of patients admitted to the specialties covered in this study at a) the study hospital in 1994/5 and b) NHS hospitals throughout England in 1994/5.

Estimates of the burden these infections imposed were derived as follows. If N is the number of patients admitted to the specialties covered in this study at the study hospital in 1994/5 (or NHS hospitals throughout England in 1994/5), C the baseline cost of treating uninfected patients, *i* the estimated incidence and *r* the estimated ratio of costs incurred by infected compared to uninfected patients, $NiC(r-1)$ provides an estimate of the national burden.

Ninety-five per cent confidence intervals were derived as follows. The estimates of the incidence of HAI and the ratio of costs incurred by infected compared to uninfected patients used to determine the burden of HAI were those derived from this study. The true population values are unknown. The sampling error of these estimates was measured by their standard errors se*i* (standard error – incidence) and se*r* (standard error – ratios of costs (LOS)). Using these values, the variance of the estimated burden of HAI was estimated as follows: $N^2C^2[i^2se_r^2+(r-1)^2\ se_i^2]$. This estimated variance was then used to obtain 95% confidence intervals for the estimates of the annual burden of HAIs, on the assumption that the sampling error in such an estimate would be approximately Normal. The square root of the estimated variance was derived and this figure multiplied by 1.96 and the resultant figure added to the estimate of the cost (and number of additional days) to derive an estimate of the upper confidence limit, and subtracted from this estimate to derive an estimate of the lower limit.

Having derived estimates of the number of patients who acquired one or more infections and estimates of the burden these infections imposed both in terms of costs and the number of additional days spent in hospital, estimates of the potential gross benefits of a 15% reduction in rates were derived.

The same methodology was subsequently used to derive site and specialty specific estimates of the burden of HAI and the potential benefits of a 15% reduction in rates, utilising site and specialty specific estimates of the incidence of HAI and the ratio of costs and LOS as appropriate.

10.3.2 The potential gross benefits of a 15% reduction in infection rates at the level of the study hospital

Tables 10.1 to 10.3 present the results of the analysis that estimated the potential benefits of a 15% reduction in HAI rates at the level of the study hospital. The estimates are limited to infections occurring in adult, non-day case patients admitted to the surgical specialties covered in this study. Table 10.1 provides details of the number of patients estimated to have acquired an infection in 1994/5. Table 10.2 presents the results of the analysis that estimated the cost of these infections and the gross benefits of a 15% reduction in rates, and Table 10.3 estimates of the number of bed days utilised as a result of infection and the number that would be released if infection rates had been 15% lower.

In 1994/5 (the year in which the study was conducted) an estimated 579 (95% CI: 500, 665) adult patients admitted to the general surgical, orthopaedic, urology, gynaecology and obstetric specialties acquired one or more HAIs. These infections were estimated to have cost the hospital sector, an additional £1,224,044 (95% CI: £898,408, £1,549,680) and affected patients were estimated to have utilised an estimated 4,308 bed days (95% CIs: 3,059, 5,558). If the infections rates had been 15% lower in 1994/5 then the crude estimates presented in Tables 10.2 and 10.3 suggest that resources valued at £183,607 (95% CI: £134,761, £232,452) may have been available for alternative use, and the same reduction in rates might have resulted in the release of 646 bed days (95% CI: 459 , 834 bed days).

The estimated cost of HAI, and the estimated benefits of a 15% reduction in rates varied considerably with site. Whilst multiple infections were estimated to impose the greatest burden, if infections occurring at just one site are considered, the results presented in Tables 10.2 and 10.3 show that UTIs, which had the lowest cost per case, were the most expensive type of infection.

Specialty specific estimates suggested that relative to the other surgical specialties the general surgical and urology specialties incurred the greatest costs from HAI, and the benefits of a 15% reduction in rates potentially could be substantial.

It should be stressed that the estimates presented in Table 10.2 represent the gross benefits of prevention: that is they represent the level of resources that might be released for alternative use. They do not represent the value that affected individuals and society as a whole place on prevention.

Table 10.1: Estimates of the number of adult non day-case patients admitted to five surgical specialties at the study hospital in 1994/5 who acquired an infection by site of infection and specialty

Specialties	Types of HAI	Incidence of HAI (%) observed in study (95% CI)	No of patients at risk	Estimated no. of patients with an HAI which presented during the in-patient period (95% CI)
All listed specialties*	All HAIs	7.5(6.4 , 8.6)	7763	579 (500 , 665)
All listed specialties*	UTI	3.5(2.8 , 4.3)	7763	274 (220 , 336)
	Chest	0.6(0.4 , 1.1)	7763	50 (29 , 82)
	SWI	1.1(0.8 , 1.6)	7763	88 (59 , 127)
	BSI	0.1(0.0 , 0.3)	7763	6 (0 , 23)
	Skin	0.5(0.3 , 0.9)	7763	41 (22 , 70)
	Other	0.6(0.3 , 1.0)	7763	47 (24 , 78)
	Multiple	0.9(0.6 , 1.4)	7763	108 (46 , 72)
General surgery	All HAIs	6.1(4.6 , 7.5)	2994	183 (138 , 225)
Orthopaedics	All HAIs	7.4(5.2 , 10.4)	1672	124 (87 , 174)
Urology	All HAIs	5.1(3.9 , 8.4)	1067	54 (42 , 90)
Gynaecology	All HAIs	12.7(9.9 , 16.8)	1702	216 (168 , 286)
Obstetrics***	All HAIs	9.3(6.2 , 14.4)	328	31 (20 , 47)

* General surgery, orthopaedics, urology, gynaecology, obstetrics (caesarean sections only)
** Number of adult non day-case patients admitted to the specialties listed at the study hospital in 1994/5
***Caesarean sections only

Table 10.2 **Estimates of the cost of HAIs occurring in adult, non day-case patients admitted to five surgical specialties at the study hospital in 1994/5 and the potential benefits of a 15% reduction in rates**

Specialties	Types of HAI	Mean costs uninfected patients	Model estimate of the ratio of costs incurred by infected compared to uninfected patients (95% CI)	Estimated number of infected patients (95% CI)	Estimated costs to hospital sector (£) (95% CI)	Estimate of resources released if rates were 15% lower (£) (95% CI)
All listed specialties*	All HAIs	1656	2.3 (2.0 , 2.6)	579 (500 , 665)	1224044 (898408 , 1549680)	183607 (134761 , 232452)
All listed specialties*	UTI	1656	1.6 (1.3 , 1.9)	274 (220 , 336)	258927 (126961 , 390893)	38839 (19044 , 58634)
	Chest	1656	2.8 (1.8 , 4.3)	50 (29 , 82)	147595 (58312 , 236879)	22139 (8747 , 35532)
	SWI	1656	1.9 (1.4 , 2.6)	88 (59 , 127)	131176 (52424 , 209927)	19676 (7864 , 31489)
	BSI	1656	6.0 (2.2 , 16.2)	6 (0 , 23)	52217 (-13163 , 117598)	7833 (-1975, 17640)
	Skin	1656	2.0 (1.2 , 3.2)	41 (22 , 70)	65963 (6667 , 125258)	9894 (1000 , 18789)
	Other	1656	2.0 (1.3 , 2.9)	47 (24 , 78)	75103 (11680 , 138525)	11265 (1752 , 20779)
	Multiple infections	1656	5.6 (3.9 , 7.9)	108 (46 , 72)	820424 (538527 , 1102320)	123064 (80779 , 165348)
General surgery	All HAIs	1338	3.9 (3.0 , 4.9)	183 (138 , 225)	696543 (431017 , 962070)	104482 (64652 , 144311)
Orthopaedics	All HAIs	2157	2.4 (1.8 , 3.3)	124 (87 , 174)	385745 (185714 , 585777)	57862 (27857 , 87867)
Urology	All HAIs	1316	2.1 (1.5 , 2.9)	54 (42 , 90)	78438 (31216 , 125659)	11766 (4682 , 18849)
Gynaecology	All HAIs	1682	1.2 (0.9 , 1.6)	216 (168 , 286)	79375 (-23905 , 182656)	11906 (-3586 , 27398)
Obstetrics***	All HAIs	2508	1.1 (0.7 , 1.6)	31 (20 , 47)	4713 (-21338 , 30763)	707 (-3201 , 4614)

* General surgery, orthopaedics, urology, gynaecology, obstetrics (caesarean sections only)
*Figures taken from Table 10.1
*Caesarean sections only

Table 10.3: Estimates of the number of additional days, adult non-day case patients admitted to five surgical specialties at the study hospital in 1994/5 and who acquired an HAI, remained in hospital and the number of bed days released if rates were 15% lower

Specialties	Types of HAI	Mean LOS uninfected patients	Model estimate of the ratio of costs incurred by infected compared to uninfected patients (95% CI)	Estimated number of infected patients** (95% CI)	Estimate of the number of additional days in hospital (95% CI)	Estimates of the number of days released if rates were reduced by 15% (95% CI)
All listed specialties*	All HAIs	6.6	2.1 (1.8 , 2.5)	579 (500 , 665)	4308 (3059 , 5558)	646 (459 , 834)
All listed specialties*	UTI	6.6	1.5 (1.3 , 1.9)	274 (220 , 336)	984 (420 , 1548)	148 (63 , 232)
	Chest	6.6	2.3 (1.4 , 3.8)	50 (29 , 82)	426 (78 , 775)	64 (12, 116)
	SWI	6.6	2.0 (1.5 , 2.9)	88 (59 , 127)	606 (207 , 1004)	91 (31 , 151)
	BSI	6.6	1.5 (0.5 , 4.4)	6 (0 , 23)	19 (-26 , 65)	3 (-4 , 10)
	Skin	6.6	2.5 (1.5 , 4.2)	41 (22 , 70)	401 (67 , 735)	60 (10 , 110)
	Other	6.6	2.7 (1.7 , 4.2)	47 (24 , 78)	516 (119 , 912)	77 (18 , 137)
	Multiple infections	6.6	4.4 (2.9 , 6.5)	108 (46 , 72)	2402 (1506 , 3298)	360 (226 , 495)
General surgery	All HAIs	5.4	3.4 (2.6 , 4.4)	183 (138 , 225)	2317 (1348 , 3286)	348 (202 , 493)
Orthopaedics	All HAIs	10.3	2.0 (1.4 , 2.7)	124 (87 , 174)	1790 (1018 , 2562)	268 (153 , 384)
Urology	All HAIs	5.1	2.5 (1.7 , 3.6)	54 (42 , 90)	937 (698 , 1176)	141 (105 , 176)
Gynaecology	All HAIs	6.1	1.3 (1.0 , 1.7)	216 (168 , 286)	100 (-341 , 541)	15 (-51 , 81)
Obstetrics**	All HAIs	7.5	1.1 (0.7 , 1.7	31 (20 , 47)	115 (30 , 201)	17 (4 , 30)

* General surgery, orthopaedics, urology, gynaecology, obstetrics (caesarean sections only)
**Figures taken from Table 10.1
***Caesarean sections only

10.3.3 National estimates of the potential gross benefits of a 15% reduction in infection rates

Tables 10.4 – 10.6 present site and specialty specific estimates of the potential benefits of a 15% reduction in infection rates occurring in adult non-day case patients admitted to the surgical specialties, covered in this study at NHS hospitals in England in 1994/5. Overall an estimated 154,920 (95% CI: 134,024, 177,943) adult non-day case patients admitted to the specialties covered in this study at other NHS hospitals in England acquired one or more HAIs in 1994/5, at a cost to the health sector of £327.78 million (95%CI: £240.58, £414.98) (in-patient costs only). Overall an estimated 1,153,726 (95% CI: 819,019, 1,488,434) additional bed days were utilised as a result of patients acquiring one or more HAIs. The magnitude of the burden imposed varied with site and specialty.

Estimates of the gross benefits of a reduction in rates indicated that a 15% reduction in rate would result in resources valued at £49.17 million (95% CI: £36.09, £62.25 million) released for alternative use. The same level of reduction in the rate would have released an estimated 173,059 bed days (95% CI: 122,853, 223,265) for alternative use. Estimates the magnitude of the level of resources released varied with site and with specialty, as indeed they did for the study hospital.

Table 10.4: **Estimates of the number of adult non day case patients admitted to five surgical specialties at NHS hospitals in England who acquired an HAI IN 1994/5 by site of infection and specialty**

Specialties	Types of HAI	Incidence of HAI (%) observed in study (95% CI)	No of patients at risk**	Estimated no. of patients with an HAI which presented during the in-patient period (95% CI)
All listed specialties*	All HAIs	7.5 (6.4 , 8.6)	2078793	154920 (134024 , 177943)
All listed specialties*	UTI	3.5 (2.8 , 4.3)	2078793	73250 (58867 , 89981)
	Chest	0.6 (0.4 , 1.1)	2078793	13471 (7708 , 21831)
	SWI	1.1 (0.8 , 1.6)	2078793	23576 (15693 , 33986)
	BSI	0.1 (0.0 , 0.3)	2078793	1684 (0 , 6076)
	Skin	0.5 (0.3 , 0.9)	2078793	10945 (5833 , 18682)
	Other	0.6 (0.3 , 1.0)	2078793	12629 (6320 , 20790)
	Multiple	0.9 (0.6 , 1.4)	2078793	19366 (12294 , 28989)
General surgery	All HAIs	6.1 (4.6 , 7.5)	804676	49085 (37015 , 60351)
Orthopaedics	All HAIs	7.4 (5.2 , 10.4)	464948	34406 (24177 , 48355)
Urology	All HAIs	5.1 (3.9 , 8.4)	223685	11408 (8724 , 18790)
Gynaecology	All HAIs	12.7 (9.9 , 16.8)	501395	63677 (49638 , 84234)
Obstetrics**	All HAIs	9.3 (6.2 , 14.4)	84089	7820 (5214 , 12109)

* General surgery, orthopaedics, urology, gynaecology, obstetrics (caesarean sections only)

**Number of adult, non-day case patients admitted to the specialties listed in the table in 1994/5. Data source: Hospital episode statistics data set 1994/5 [221]

***Caesarean sections only

Table 10.5: Estimates of the cost of HAIs occurring in adult, non day-case patients admitted to five surgical specialties at NHS hospitals in England in 1994/5 and the potential benefits of a 15% reduction in rates

Specialties	Types of infection	Mean costs uninfected patients	Model estimate of the ratio of costs incurred by infected compared to uninfected patients (95% CI)	Estimated number of infected patients** (95% CI)	Estimated costs to hospital sector £ million (95% CI)	Estimate of resources released if rates were 15% lower £ million (95% CI)
All listed specialties*	All HAIs	1656	2.3 (2.0 , 2.6)	154920 (134024 , 177943)	327.78 (240.58 , 414.98)	49.17 (36.09 , 62.25)
All listed specialties*	UTI	1656	1.6 (1.3 , 1.9)	73250 (58867 , 89981)	69.34 (34.00 , 104.67)	10.40 (5.10 , 15.70)
	Chest	1656	2.8 (1.8 , 4.3)	13471 (7708 , 21831)	39.52 (15.61 , 63.43)	5.93 (2.34 , 9.51)
	SWI	1656	1.9 (1.4 , 2.6)	23576 (15693 , 33986)	35.13 (14.04 , 56.21)	5.27 (2.11 , 8.43)
	BSI	1656	6.0 (2.2 , 16.2)	1684 (0 , 6076)	13.98 (-3.52 , 31.49)	2.10 (-0.53 , 4.72)
	Skin	1656	2.0 (1.2 , 3.2)	10945 (5833 , 18682)	17.66 (1.79 , 33.54)	2.65 (0.27 , 5.03)
	Other	1656	2.0 (1.3 , 2.9)	12629 (6320 , 20790)	20.11 (3.13 , 37.09)	3.02 (0.47 , 5.56)
	Multiple infections	1656	5.6 (3.9 , 7.9)	19366 (12294 , 28989)	146.77 (71.28 , 222.25)	22.02 (10.69 , 33.34)
General surgery	All HAIs	1338	3.9 (3.0 , 4.9)	49085 (37015 , 60351)	187.21 (115.84 , 258.57)	28.08 (17.38 , 38.79)
Orthopaedics	All HAIs	2157	2.4 (1.8 , 3.3)	34406 (24177 , 48355)	107.27 (51.64 , 162.89)	16.09 (7.75 , 24.43)
Urology	All HAIs	1316	2.1 (1.5 , 2.9)	11408 (8724 , 18790)	16.44 (6.54 , 26.34)	2.47 (0.98 , 3.95)
Gynaecology	All HAIs	1682	1.2 (0.9 , 1.6)	63677 (49638 , 84234)	23.38 (-7.04 , 53.81)	3.51 (-1.06 , 8.07)
Obstetrics***	All HAIs	2508	1.1 (0.7 , 1.6)	7820 (5214 , 12109)	1.21 (-5.47 , 7.89)	0.18 (-0.82 , 1.18)

* General surgery, orthopaedics, urology, gynaecology, obstetrics (caesarean sections only)
**Figures taken from Table 10.4
***Caesarean sections only

Table 10.6: Estimates of the number of additional days adult, non day case patients, admitted to selected specialties at NHS hospitals in England 1994/5 and who acquired an HAI remained in hospital and the number of bed days released if rates were 15% lower

Specialties	Types of HAI	Mean LOS uninfected patients	Model estimates of the ratio of LOS infected and uninfected patients (95% CI)	Estimated number infected patients** (95% CI)	Estimated number of additional days (95% CI)	Estimated number of days released if rates were reduced by 15% (95% CI)
All listed specialties*	All HAIs	6.6	2.1 (1.8 , 2.5)	154920 (134024 , 13261)	1153726 (819019 , 1488434)	173059 (122853 , 223265)
All listed specialties*	UTI	6.6	1.54 (1.3 , 1.9)	73250 (58867 , 89981)	263457 (112505 , 414409)	39519 (16876 , 62161)
	Chest	6.6	2.28 (1.4 , 3.8)	13471 (7708 , 21831)	114149 (20846 , 207452)	17122 (3127 , 31118)
	SWI	6.6	2.04 (1.5 , 2.9)	23576 (15693 , 33986)	162203 (55564 , 268843)	24330 (8335 , 40326)
	BSI	6.6	1.47 (0.5 , 4.4)	1684 (0 , 6076)	5198 (-6884 , 17281)	780 (-1033 , 2592)
	Skin	6.6	2.49 (1.5 , 4.2)	10945 (5833 , 18682)	107291 (17856 , 196726)	16094 (2678 , 29509)
	Other	6.6	2.66 (1.7 , 4.2)	12629 (6320 , 20790)	138123 (31912 , 244333)	20718 (4787 , 36650)
	Multiple infections	6.6	4.36 (2.9 , 6.5)	19366 (12294 , 28989)	429706 (189782 , 669631)	64456 (28467 , 100445)
General surgery	All HAIs	5.4	3.35 (2.6 , 4.4)	49085 (37015 , 60351)	622795 (362403 , 883187)	93419 (54360 , 132478)
Orthopaedics	All HAIs	10.3	1.95 (1.4 , 2.7)	34406 (24177 , 48355)	337204 (122425 , 551983)	50581 (18364 , 82797)
Urology	All HAIs	5.1	2.48 (1.7 , 3.6)	11408 (8724 , 18790)	86385 (85809 , 86961)	12958 (12871 , 13044)
Gynaecology	All HAIs	6.1	1.30 (1.0 , 1.7)	63677 (49638 , 84234)	116961 (-13072 , 246994)	17544 (-1961 , 37049)
Obstetrics***	All HAIs	7.5	1.07 (0.7 , 1.7)	7821 (5214 , 12109)	4177 (-17804 , 26159)	627 (-2671 , 3924)

* General surgery, orthopaedics, urology, gynaecology, obstetrics (caesarean sections only)
**Figures taken from Table 10.4
***Caesarean sections only
LOS – length of stay

10.4 The net benefits of investment in infection control

The preceding sections presented estimates of the gross benefits of investment in infection control that may result if a 15% reduction in rates were achieved. No attempt was made to take into account the costs of prevention and control activities and their actual effectiveness. The above examples simply highlight the magnitude of the level of resources that might be released if a reduction at the 15% level was achieved. This section explores how the results of this study may be incorporated into simple economic models to demonstrate the net benefits of investment in infection control practices.

Models of the net benefits of investment in prevention activities can be derived from information on infection rates;
the cost of the infection control practice to be evaluated and its

- efficacy (assuming 100% compliance);

the cost of alternative strategies which would need to be introduced to maximise compliance and the level of compliance they are expected to achieve; and
the magnitude, nature and distribution of the economic burdens that may have resulted had the HAIs not been prevented.

Data on infection rates can be obtained from a variety of sources including hospital records, the literature and national surveillance schemes. Data on the cost of selected infection control practices and the cost of strategies to enhance compliance with a given practice can generally be relatively easily estimated, and data on the cost of the burden that may have resulted had the HAIs not been prevented can be obtained from studies such as this. However, data on the efficacy of interventions and strategies that aim to enhance compliance and hence effectiveness are a little more difficult to obtain. Whilst a number of studies have demonstrated the effectiveness of surveillance and feedback of results to the appropriate personnel,[164 233] with the exception of studies that have assessed the efficacy of specific antibiotics there is a marked lack of information on the efficacy of specific infection control activities. Lack of information on the effectiveness of infection control practices was highlighted by

Thames Valley University, when drafting infection control guidelines for the prevention of HAIs.[234] When drafting these guidelines prevention activities were categorised according to the quality of the supporting evidence.

Category 1 included activities where there were generally consistent findings from a range of evidence derived from well designed experimental studies. Category 2 included activities for which evidence of effectiveness was based on a single acceptable study, or a weak or inconsistent finding in multiple acceptable studies. Category 3 included those activities for which there was limited scientific evidence that did not meet all the criteria of 'acceptable studies', or an absence of directly applicable studies of good quality. This included published or unpublished expert opinion. The majority of the activities fell within category three.[235]

In the absence of rigorous data on the efficacy of a particular intervention models can be developed which assess the potential benefits of prevention assuming different levels of effectiveness. Information on the break-even point given different levels of effectiveness can subsequently be derived from these models. That is the point at which the potential benefits cover the cost of the intervention and any further reduction in rates result in net benefits. This information can subsequently be used to inform decision marking regarding investment in the activity assessed.

The following presents a worked example of how this could be achieved. The example looks at the problem of catheter related UTIs; it represents a re-working of a study by Plowman *et al* [215] but incorporates data from the work presented here. A copy of the paper by Plowman et al[215] can be found at the back of this thesis.

10.4.1 An economic model to assess the cost and benefits of the routine use of silver alloy coated urinary catheters to reduce the risk of urinary tract infections in catheterised patients

As reported in Chapter 2, prevalence studies have generally found urinary tract infections (UTIs) to be the most common type of hospital acquired infection accounting for between 21 and 45% of all HAIs identified.[7 19 20 22] Studies which have assessed the incidence of urinary tract infections in patients admitted to both medical and surgical specialties suggest that between 1 and 3% acquire a urinary tract infection,[47 81 82] whilst a study that was limited to the incidence of infections occurring in surgical, urology, gynaecology and orthopaedic patients who had an operative procedure found that 6.3% acquired a UTI.[14] In this study the overall incidence of UTIs in patients admitted to the general surgical, orthopaedic, urology, gynaecology and, if the patient had a caesarean section, the obstetric specialties was 4.1% (95% CI: 3.3, 4.9).

These infections may result in additional morbidity[82 125 131 144 145] and in some cases mortality,[112 122] a prolonged hospital stay and additional costs incurred by the hospital sector as a result of additional in-patient care.[14 69 172 207 236] The results of this study indicated that on average UTIs cost the hospital sector an additional £944 (95% CI: £441, £1446) per case and prolonged the LOS by 3.27 (95% CI: 1.25. 5.28) days. Further costs are borne by the secondary and primary health care sector following discharge from hospital, and by patients and their carers.

A key risk factor for these infections is the presence of a urinary catheter,[14 134 137 138 143] with an estimated 80% of hospital acquired UTIs being associated with the presence of this device.[237] In an endeavour to reduce the infection risk associated with urinary catheters, silver alloy coated catheters have been developed. A number of trials have found these catheters to reduce the infection risk.[238-244] The silver alloy coating prevents the adherence of microbes to the catheter wall and this reduces the risk of infections being established. However, whilst these trials indicate that silver alloy coated catheters appear to

be effective at reducing the patients risk of acquiring a UTI, the level of effectiveness has been found to vary, this perhaps reflecting variations in case mix and the underlying infection rate. A meta-analysis of eight clinical trials found that silver alloy coated catheters, when compared to non-coated catheters, had a preventive effect, and this effect was over and above other coatings such as silver oxide coatings,[240] that have been removed from the market in the US. One trial demonstrated that up to 48% of hospital acquired UTIs may be prevented through the use of silver alloy coated urinary catheters.[241]

Whilst studies have demonstrated the effectiveness of these catheters their routine use has cost implications. Silver alloy coated catheters are more expensive that the catheters routinely used in hospitals in England and Wales: in 1994/5 silver–alloy coated catheters cost an additional £9 each.[245] As such before routine use can be advocated the potential costs and benefits associated with their routine use in a particular clinical setting needs to be assessed.

The following sections present a model for assessing the potential costs and benefits of the routine use of silver alloy coated catheters. This is followed by an illustrative model of the potential costs and benefits of their routine use in patients admitted to the specialties covered in this study at the study hospital in 1994/5.

10.4.2 Aims and objectives of the economic model

The model aims to assess the following:

i. the number of hospital acquired UTIs occurring in catheterised patients admitted to the specialties of interest at one or more hospital.

ii. the economic burden these infections impose on the hospital sector as a result of additional in-patient care

iii. the number of extra days infected patients remain in hospital.

iv. the potential benefits of the routine use of silver alloy coated catheters estimated as the value of resources and bed days released for alternative use.

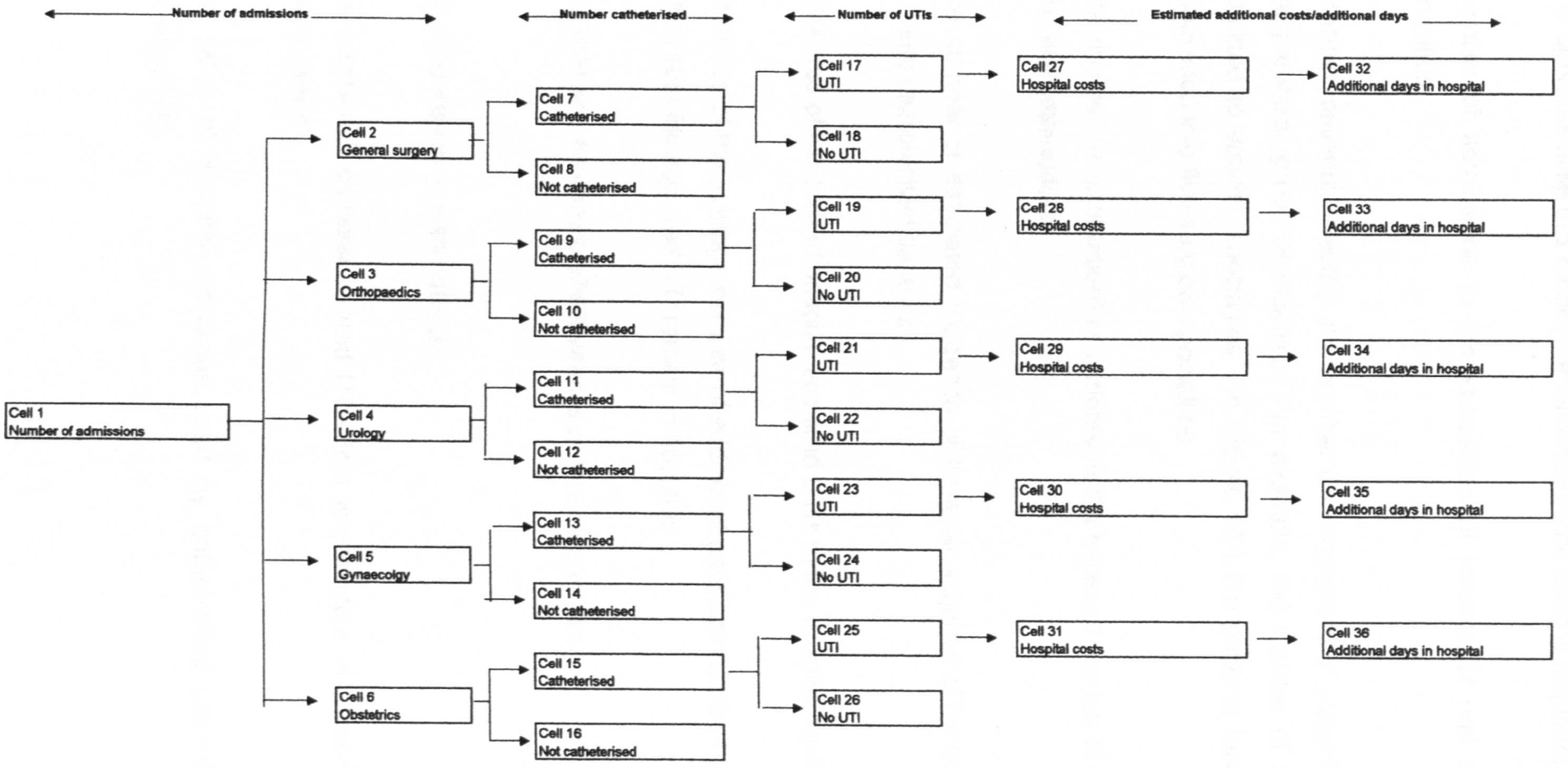
10.4.3 The structure of the economic model

Figure 10.1 illustrates the structure of the model. The starting point is the number of admissions to the specialties of interest (cell 1). These patients are then sub-divided into the specialty groups of interest (cells 2-6). Figure 10.1 shows 5 surgical specialties, however this could be adapted to reflect the needs of the user. The patient groups of interest are then further subdivided into those who are catheterised and those not catheterised (cells 7-16). The estimated number of hospital acquired UTIs that might occur in these catheterised patients are then determined based on the specialty specific incidence of UTIs (cells 17-26). Estimates of the economic impact these infections place on the hospital sector are then derived by multiplying the number of UTIs by an appropriate estimate of the additional cost of these infections (cells 27-31) and the number of extra days patients remain in hospital (cells 32-36).

Specialty specific estimates of the additional costs associated with the routine use of silver alloy coated catheters, as compared to non-coated catheters, are then derived by multiplying the additional cost of the catheter by the number of patients catheterised (cells 7, 9,11, 13, 15). The potential gross benefits (value of resources and the number of days released for alternative use) are then derived for varying levels of effectiveness (0%-100%), and the net benefits derived by subtracting the cost of the intervention from the estimated gross benefits. Finally, the costs of the intervention can be plotted against the benefits that might accrue assuming different levels of effectiveness and the cut off point where potential benefits are equal to the costs of the intervention identified. Any further reduction in rates would result in net benefits.

Sensitivity analysis can subsequently be conducted to assess the impact that varying the incidence of UTIs and the cost per case has on the results obtained.

Figure 10.1: The structure of an economic model to assess the costs and benefits of an intervention to prevent catheter associated urinary tract infections



In order to operationalise this model the following information is required:

i. Number of admissions to the specialties of interest at one or more hospitals.

ii. Of those patients selected, the number (or proportion) of patients within the particular group of interest. For example, the number of patients admitted to specific specialties. In Figure 10.1 the patients have been subdivided into five surgical specialties.

iii. The number (or proportion) of patients in the selected groups of interest who are catheterised.

iv. The number or estimated incidence of hospital acquired UTIs occurring in these catheterised patients.

v. Estimates of the cost of hospital acquired UTIs to the hospital sector.

vi. Estimates of the average number of additional days catheterised patients with a hospital acquired UTI remain in hospital.

vii. The cost and estimated effectiveness of the intervention.

The model produces five main outputs:

i. The number of catheter related UTIs that might occur in a pre-defined patient group.

ii. The value of hospital resources used by catheterised patients who acquire a UTI

iii. The number of additional bed days utilised as a result of patients acquiring a UTI.

iv. The net financial benefits associated with the routine use of sliver alloy coated catheters assuming different levels of effectiveness.

v. The number of bed days released for alternative use assuming different levels of effectiveness

10.4.4 Illustrative model

A model to assess the costs associated with catheter associated hospital acquired UTIs occurring in adult (≥ 18 years of age) non-day case admissions to five surgical specialties at the study hospitals in 1994/5 (Figure 10.2), and the potential benefits of introducing the routine use of silver alloy coated urinary catheters (Table 10.7) was developed. The model utilises data obtained from the study hospital together with the results of this work. Details of the data sources used and the output of this model are given below.

Number of admissions (cell 1)

Data on the number of adult (≥ 18 years of age), non-day case admissions to the surgical specialties of the study hospital were obtained from the study hospital's database. In 1994/5 there were 7763 admissions that met this criteria.

Number of patients admitted to the different surgical specialties (cells 2-6)

Data on the number of patients admitted to the five surgical specialties included in this model were obtained from the study hospital's database. In 1994/5 2994 (38.6%) of the 7763 adult non-day case admissions to the surgical specialties listed were general surgical admissions, 1672 (21.5%) were orthopaedic admissions, 1067 (13.7%) urology admissions, 1702 (21.9%) gynaecology admissions and 328 (4.2%) obstetric admissions who underwent a caesarean section.

The number of patients catheterised (cells 7-16)

Estimates of the number of patients catheterised were derived by applying estimates of the proportion of patients catheterised at some point during their admission to the number of admissions. Data on catheterisation rates were not routinely collected at the study hospital and as such the model utilises data obtained in this study. Of those patients recruited into this study 17.6% of surgical patients; 6.9% of orthopaedic patients; 47.0% of urology patients; 19.5% of gynaecology patients and 9.0% of obstetric patients were catheterised at some point during their admission to hospital.

Number (or percentage) of catheterised patients who acquire a UTI (cells 17-26)

Estimates of the number of patients who acquired a UTI were derived using specialty specific estimates of the incidence of UTIs in catheterised patients derived from this study. The incidence of UTIs in catheterised general surgical patients was 7.2% (95% CI: 3.3, 13.2), in orthopaedic patients 6.1% (95% CI: 1.2, 16.9), in urology patients 4.5% (95% CI: 2.5, 7.3), in gynaecology patients 18.0% (95% CI: 12.0, 25.4) and in obstetric patients 6.3 (95% CI: 1.7, 15.2).

The value of resources used as a result of additional in-patient care

Estimates of the value of resources used as a result of additional in-patient care were derived by multiplying the estimated cost per case derived in this study by the number of infections. Estimates derived from the generalised linear modelling analysis indicated that, on average, UTIs cost the hospital sector an additional £944 (95% CI: £441, £1,446) per case as a result of additional in-patient care.

The number of additional days catheterised patients with a UTI remain in hospital

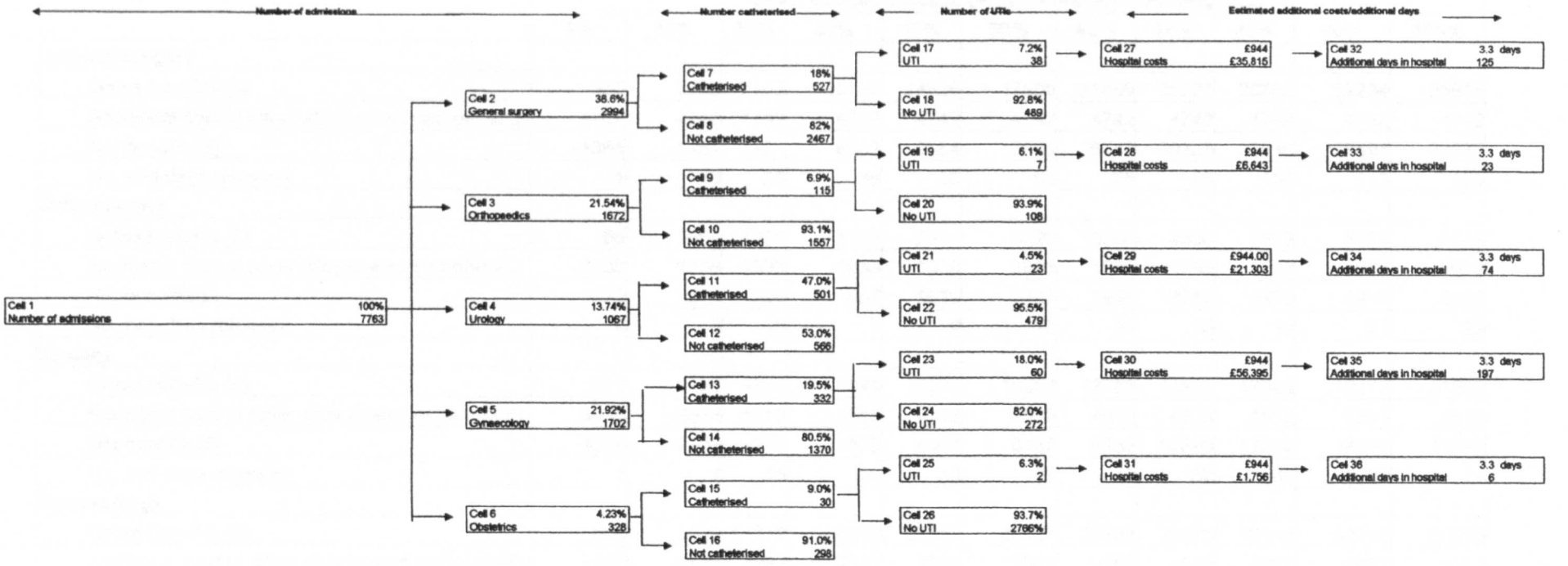
Estimates of the number of additional days catheterised patients with a UTI remained in hospital were derived by applying the model estimates of the impact of UTIs on LOS derived in this study, to the number of infections estimated to have occurred. Estimates derived from the generalised linear modelling analysis indicated that, on average, patients who acquired a UTI remained in hospital an additional 3.3 days (95% CI: 1.3, 5.3).

Estimating the potential benefits of the routine use of silver alloy coated catheters

Having identified the number of patients who acquired a UTI, and the estimated impact these infections have on hospital sector resource use, the final stage was to identify the potential savings that might result from the routine use of silver alloy coated catheters. In order to estimate these benefits information on the cost of the intervention and its estimated level of effectiveness is required. As indicated above, in 1994/5 the additional cost of silver alloy coated catheters compared to non-coated catheters was £9.[245] Estimates of the cost of this intervention can therefore be derived by applying this figure to the number of catheterised patients within each specialty (cells 7,9,11,13 and 15 in Figure 10.2). Table 10.7 presents specialty specific estimates of the costs that would be incurred if silver alloy coated catheters were in routine use.

Estimates of the potential gross and net benefits of prevention were subsequently derived for varying levels of effectiveness ranging from 0%-100% (Table 10.7). Finally the costs and potential benefit were plotted against each other (Figures 10.3 – 10.7).

Figure 10.2: An economic model of the costs and benefits of the routine use of silver alloy coated catheters in adult non-day case patients admitted to the surgical specialties of one hospital in England in 1994/5



Assumptions

Assumptions	General surgery	Orthopaedics	Urology	Gynaecology	Obstetrics
Catheterisation rate	17.6%	6.9%	47.0%	19.5%	9.0%
UTI incidence rate	7.2%	6.1%	4.5%	18.0%	6.3%
Estimated cost per case	£944	£944	£944	£944	£944
Estimated number of additional days per case	3.3	3.3	3.3	3.3	3.3

Table 10.7: Estimates of the potential costs and benefits associated with the routine use of silver alloy coated catheters in adult non-day case admissions admitted to five surgical specialties at one NHS hospital in 1994/5

	Level of effectiveness of catheters at preventing UTIs										
	1%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
General surgery											
Gross benefits (£)	358	3582	7163	10745	14326	17908	21489	25071	28652	32234	35815
Additional cost of silver alloy coated catheters(£)	4742	4742	4742	4742	4742	4742	4742	4742	4742	4742	4742
Net benefits(£)	-4384	-1161	2421	6002	9584	13165	16747	20328	23910	27491	31073
No. bed days released	1	13	25	38	50	63	75	88	100	113	125
Orthopaedics											
Gross benefits (£)	66	664	1329	1993	2657	3322	3986	4650	5315	5979	6643
Additional cost of silver alloy coated catheters(£)	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038
Net benefits(£)	-972	-374	290	955	1619	2283	2948	3612	4276	4941	5605
No. bed days released	0	2	5	7	9	12	14	16	19	21	23
Urology											
Gross benefits (£)	213	2130	4261	6391	8521	10652	12782	14912	17043	19173	21303
Additional cost of silver alloy coated catheters(£)	4513	4513	4513	4513	4513	4513	4513	4513	4513	4513	4513
Net benefits(£)	-4300	-2383	-253	1878	4008	6138	8269	10399	12529	14660	16790
No. bed days released	1	7	15	22	30	37	45	52	60	67	74
Gynaecology											
Gross benefits (£)	564	5639	11279	16918	22558	28197	33837	39476	45116	50755	56395
Additional cost of silver alloy coated catheters(£)	2987	2987	2987	2987	2987	2987	2987	2987	2987	2987	2987
Net benefits(£)	-2423	2652	8292	13931	19571	25210	30850	36489	42129	47768	53408
No. bed days released	2	20	39	59	79	99	118	138	158	177	197
Obstetrics											
Gross benefits (£)	18	176	351	527	702	878	1053	1229	1404	1580	1756
Additional cost of silver alloy coated catheters(£)	266	266	266	266	266	266	266	266	266	266	266
Net benefits(£)	-248	-90	85	261	437	612	788	963	1139	1314	1490
No. bed days released	0	1	1	2	2	3	4	4	5	6	6

Figure 10.3: Estimated costs and benefits of the routine use of silver alloy coated catheters in adult, non-day case patients admitted to the general surgical specialty of an NHS hospitals in England

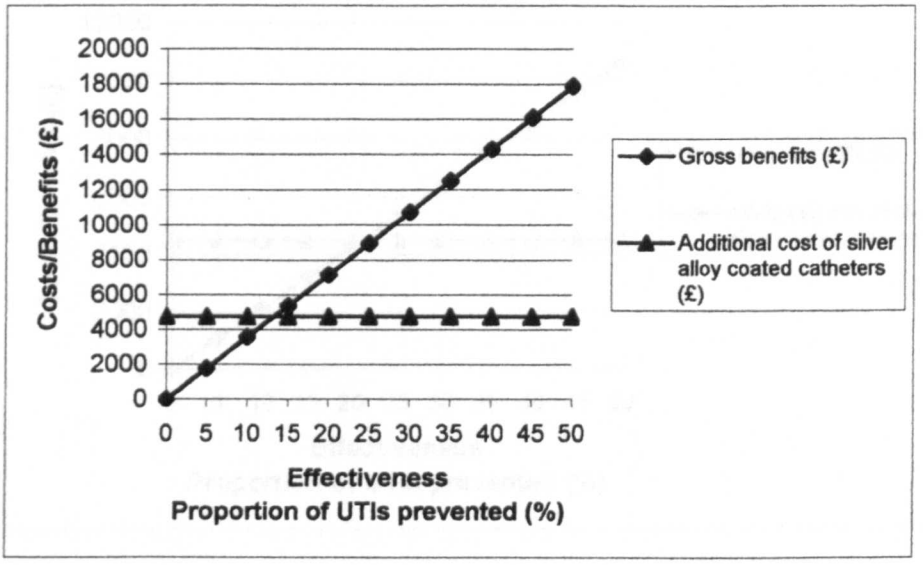


Figure 10.4: Estimated costs and benefits of the routine use of silver alloy coated catheters in adult, non-day case patients admitted to the orthopaedic specialty of an NHS hospitals in England

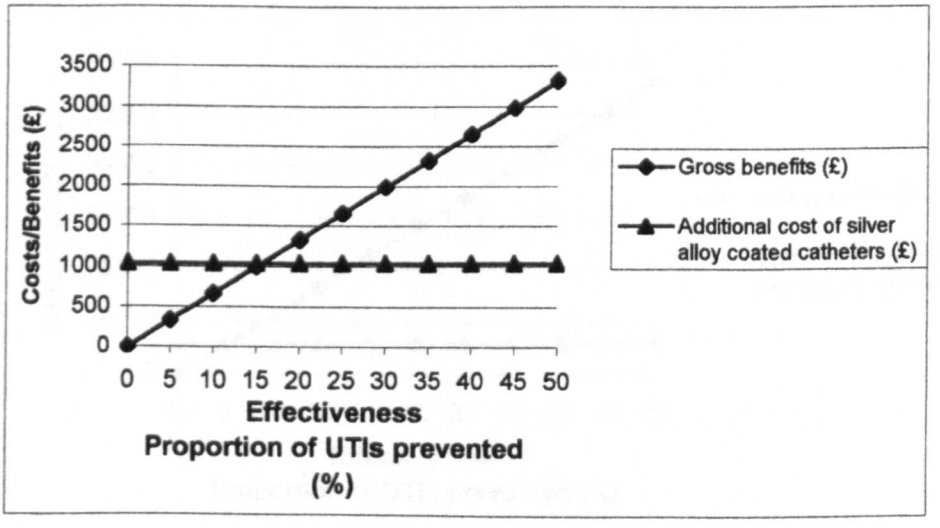


Figure 10.5: Estimated costs and benefits of the routine use of silver alloy coated catheters in adult, non-day case patients admitted to the urology specialty of an NHS hospitals in England

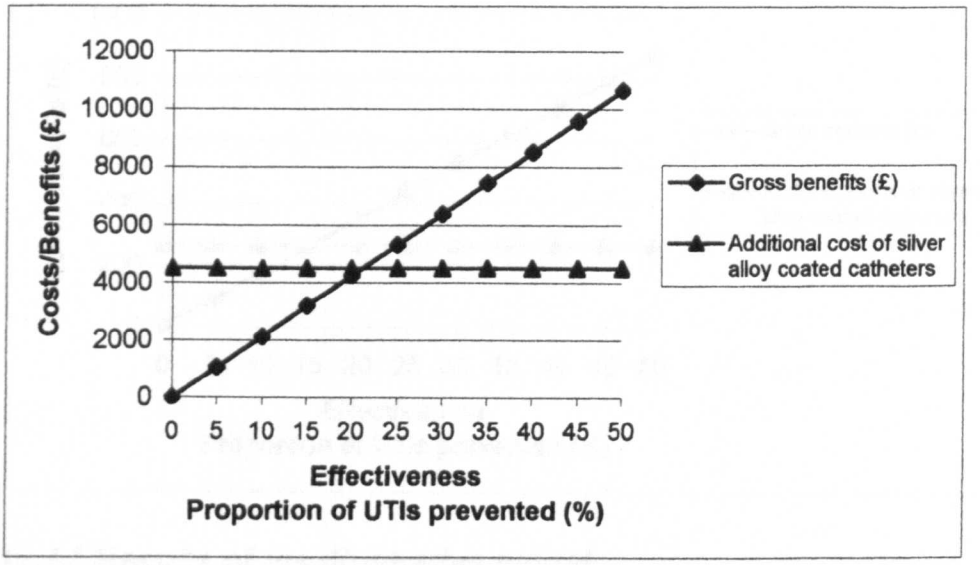


Figure 10.6: Estimated costs and benefits of the routine use of silver alloy coated catheters in adult, non-day case patients admitted to the gynaecology specialty of an NHS hospitals in England

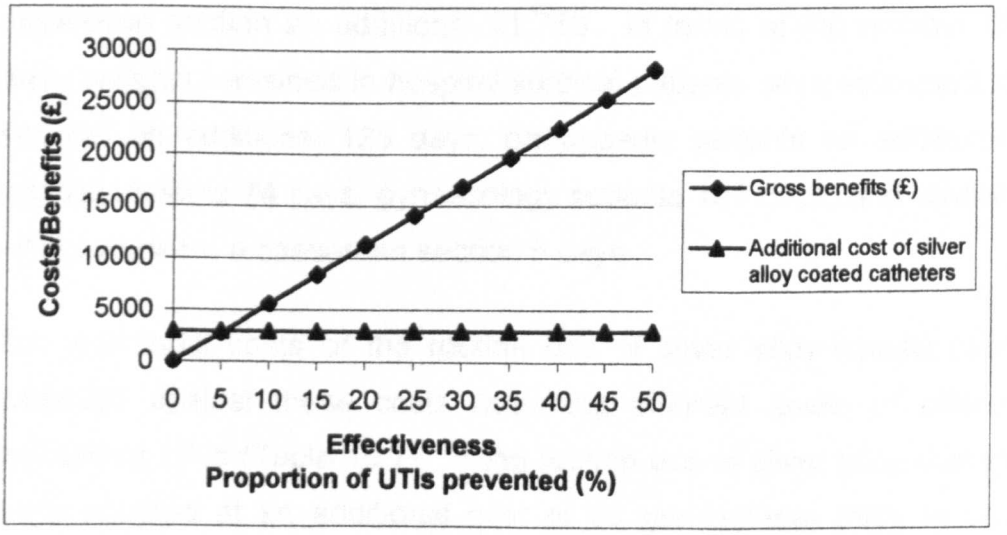
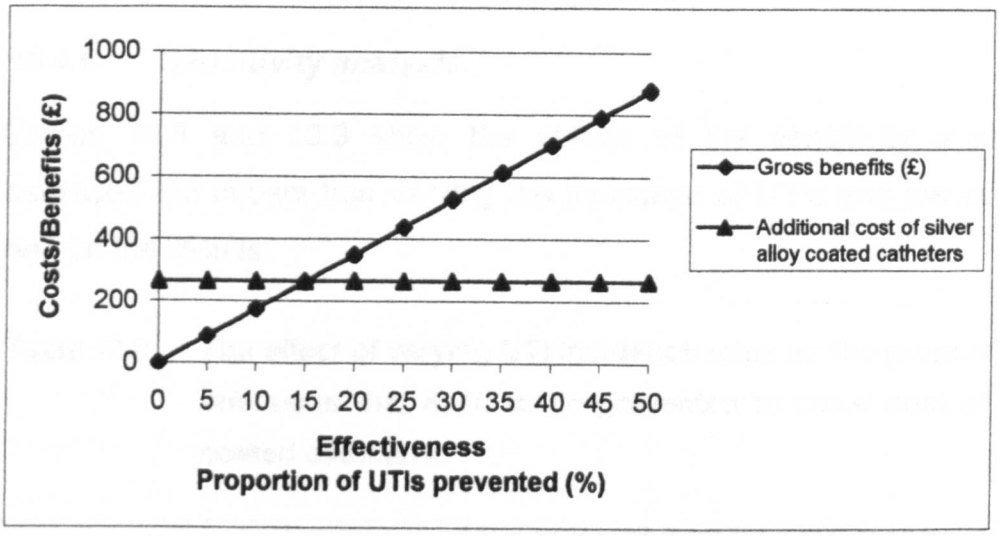


Figure 10.7: Estimated costs and benefits of the routine use of silver alloy coated catheters in adult, non-day case patients admitted to the obstetric specialty of an NHS hospitals in England



10.4.5 Results of the illustrative model

If the assumptions detailed above are accepted, the model suggests that 129 surgical patients acquired a catheter related UTI in 1994/5 (Figure 10.2). General surgical patients were estimated to cost the hospital sector an additional £35,815, orthopaedic patients an additional £6,643, urology patients £21,303, gynaecology patients £56,395, and obstetric patients who underwent a caesarean section an additional £1,756. In terms of the number of additional days patients remained in hospital surgical patients were estimated to remain in hospital an additional 125 days, orthopaedic patients an additional 23 days, urology patients 74 days, gynaecology patients 197 days, and obstetric patients who underwent a caesarean section 6 days.

The additional costs of the routine use of silver alloy coated catheters was balanced against these costs assuming different levels of effectiveness at preventing UTIs (Table 10.7). If the routine use of silver alloy coated catheters were adopted at an additional cost of £9 per catheter then, in order for the benefits to outweigh the costs, 13.2% of infections occurring in general surgical patients would need to be prevented to cover the costs, 15.6% in orthopaedic patients, 21.2% in urology patients, 5.3% in gynaecology patients and 14.4% in obstetric patients who underwent a caesarean section (Figures 10.3 – 10.7).

The results of one clinical trial suggest that up to 48% of hospital acquired UTIs can be prevented.[241] Clearly at this level of effectiveness the benefits of the silver alloy coated catheters significantly outweigh the costs.

10.4.6 Sensitivity analysis

Tables 10.8 and 10.9 show the results of the sensitivity analysis, which assessed the impact that varying the incidence of UTIs and the cost per case had on the results.

Table 10.8: The effect of varying UTI incidence rates on the proportion of infections that need to be prevented to cover cost of silver alloy coated catheters*

Incidence rate (%)	Proportion of infections that need to be prevented to cover cost of silver alloy coated catheters* (%)
2	47.7
4	23.8
6	15.9
8	11.9
10	9.5
12	7.9
14	6.8
16	6.0
18	5.3
20	4.8

*All other assumptions (additional cost of catheter, cost per case) remain unchanged

Table 10.9: The effect of varying the cost per UTI on the proportion of infections that need to be prevented to cover cost of silver alloy coated catheters*

	Proportion of infections that need to be prevented to cover cost of silver alloy coated catheters* (%)				
Cost per case	General surgery	Orthopaedics	Urology	Gynaecology	Obstetrics
50% of cost used	26.6	31.3	42.4	10.6	30.3
100% of cost used	11.2	15.6	21.2	5.3	14.4
150% of costs used	8.8	10.4	12.1	3.5	10.1

~ All other assumptions (additional cost of catheter, cost per case) remain unchanged

As the individual parameters are decreased the intervention needs to be more effective for the benefits to cover the costs. As they are increased the

intervention needs to be less effective to cover the costs. For example, if the incidence of UTIs in catheterised general surgical patients was just 2%, rather than 7.2% as assumed in the model, then providing all the other assumptions are thought to be valid, 47.7% of the expected UTIs occurring in catheterised general surgical patients would need to be prevented if the costs of the intervention were to be covered. However, if the specialty specific incidence rates are higher than that assumed in the model, then providing the other assumptions are accepted, a lower percentage of infections would need to be prevented to cover the cost of the intervention. For example, if the incidence of UTIs in catheterised general surgical patients was 12%, rather than the 7.2%, as assumed in the model, a 7.9% reduction in the incidence of UTIs in catheterised surgical patients would be needed to cover the cost of the intervention.

The effects of altering more than one parameter at a time were not explored in this model.

10.4.7 Validity of the model

The validity of this model is dependent on how realistic the structure of the model is and how accurately the estimates of the parameters used reflect what is happening in the patient group of interest. The illustrative model presented was based on information derived from this study. It should be noted that the specialty specific incidence rates derived had wide confidence intervals and this should be taken into account when interpreting the results. However, it should also be noted that this particular model is for illustrative purposes. If the results were to be used to inform decision making, the impact of varying the incidence should be taken into consideration.

10.4.8 Interpreting the results of the model

The model provides information on the number of UTIs occurring in catheterised patients; the number and cost of extra bed days utilised as a result of UTIs; and the net financial benefits associated with the routine use of silver alloy coated

catheters. Studies that have assessed the effectiveness of the use of this type of catheter suggest that up to 48% of infections can be prevented.[241] However, the validity of some of the published estimates has been questioned,[243] and as mentioned earlier, to some extent the level of effectiveness achieved depends on the scope for reducing the incidence of this type of infection. Nevertheless the evidence to date does appear to suggest a preventative effect, and the results of this model demonstrate that even at relatively low levels of effectiveness the cost of their routine use can be recouped.

However, the results of the sensitivity analysis demonstrate that if the specialty specific incidence rates used in this model are an overestimate of the actual incidence rates, then the routine use of these catheters may be an expensive option unless a high proportion of infections can be prevented. The routine use of silver alloy catheters in patients in which the infection rate is just 2% would necessitate a 47.7% reduction in rates if the costs were to be recouped. However, with the exception of obstetric patients the lower confidence rate was above 2% for all specialties.

When relatively conservative estimates of the additional costs resulting from HAI were introduced into the model, the results indicated that with the exception of the urology specialty, the catheters would need to be effective at preventing between 11% and 23% of infections if the cost of the catheters were to be covered, the precise level varying with specialty. The level of effectiveness needed for urology patients was somewhat higher - 42%. However, if the estimates used are underestimates of the value of resources that might be released, then the catheters would only have to be effective at preventing between 3.5 and 12.1% of infections, if the costs of the catheters were to be covered, again the actual level of effectiveness needed varying with specialty.
It should be noted that the sensitivity analysis did not consider the impact of varying more than one parameter at a time. If the incidence of UTIs and the additional cost per case used in this model are both thought to overestimate the

situation in a given setting, the benefits may no longer outweigh the cost of the intervention.

However, the model did not assess the benefits associated with a reduction in secondary bactereamias, a known sequela to UTIs. Studies indicated that between 1% and 5% of patients with a UTI will develop a secondary bacteraemia.[81 82 144] Acquisition of a BSI following a UTI may further prolong the patients length of hospital stay and represent an additional burden to the health sector. As such the benefits of preventing hospital acquired UTIs may have been underestimated in the illustrative model. If the use of silver alloy coated catheters are effective in preventing UTIs in patients who in the absence of this intervention would have acquired both a UTI and a bacteraemia, the benefits of preventing UTIs through the routine use of this intervention will increase.

When interpreting the benefits the user should be aware that the cost of the infection, if avoided, will not all be realised as a cash saving. Many of the costs/benefits are fixed costs and expenditure on these resources is committed at the beginning of a time period and cannot be recovered. However, the variable costs/benefits (for example drugs, and other consumable items), which represent a smaller proportion of the total costs, would show as cash savings and as such expenditure that could be avoided.

While the fixed costs avoided will not all be realised as cash savings, they do represent economic benefits as these resources could be deployed to produce other outputs (instead of treating the infection). NHS resources are severely limited and so there is almost certainly an opportunity cost associated with using fixed resources to treat hospital acquired UTIs. This implies a positive value for the fixed resources freed up by prevention control activities. It is therefore justified to use the full cost data (fixed plus variable costs) to represent the benefits.

10.4.9 Potential applications

The model described represents a flexible tool which could easily be adapted to the specific needs of the user. It may be of particular interest to infection control nurses and doctors who wish to demonstrate the magnitude of the burden of this type of infection and the benefits associated with the routine use of silver alloy coated catheters. The information derived from the model may be used to justify the additional expenditure associated with this intervention, and to change policy regarding infection control practice.

While the model presented focuses on UTIs occurring in catheterised patients and the routine use of silver alloy coated catheters as a means of reducing this type of infection, the model could equally be adapted to assess the benefits of an alternative infection prevention intervention.

10.5 Conclusion

In this chapter estimates of the gross benefits that might result if a 15% reduction in infections rates in adult non-day case patients admitted to the five surgical specialties covered in this study, at the study hospital or at the national level were achieved, have been presented. Estimates of both the value of resources that might be released for alternative use and the number of bed days released have been presented. The results demonstrate that the magnitude of these benefits, should this reduction be achieved, is likely to be substantial. However, achieving such a reduction is not cost free. As such the net benefits will be dependent on the costs of achieving such a reduction in rates. With the exception of studies that have assessed the costs and benefits of surveillance, and prophylactic antibiotics, few studies have assessed the cost and benefits of selected infection control practices. In the absence of such studies, economic models can be developed, utilising data from a variety of sources, and the information derived used to inform decision making regarding resource allocation and practice. An illustrative model that assessed the cost and benefits of the routine use of silver alloy coated catheters was presented and the results discussed. The use of models together with the findings of this study will be discussed further in the following chapter.

CHAPTER 11
DISCUSSION AND CONCLUSIONS

11.1 Introduction

In this chapter the results of this study will be discussed. The chapter begins with an overview of the main results and how they compare to those derived in earlier published studies. The strengths and limitations of this research are then discussed in sections 11.3 and 11.4, followed by a discussion of methodological issues in section 11.5. The implications of the study findings for policy and practice are discussed in section 11.6, areas for future research identified in section 11.7 and conclusions drawn in section 11.8.

11.2 Overview of results

This study provides important data on the incidence of HAIs occurring in adult non-day case patients admitted to selected surgical specialties of a district general hospital in England, independent risk factors for these infections, and estimates of the economic burden these infections place on the hospital sector as a result of additional in-patient care.

11.2.1 Incidence of HAI

Of the 2469 patients included in this study 7.5% (95% CI: 6.4%, 8.6%) acquired and presented with one or more HAIs during their in-patient stay. Twenty-nine per cent of infections presented within the first four days of admission, over 50% within the first six days, and 75% within nine days of admission.

The incidence of HAI varied with admission specialty. The incidence of HAI in gynaecology patients was 12.7% (95% CI: 9.9%, 16.8%); 9.3% (95% CI: 6.2%, 14.4%) in obstetric patients who had undergone a caesarean section; 7.4% (95% CI: 5.2%, 10.4%) in orthopaedic patients; 6.1% (95% CI: 4.6%, 7.9%) in general surgical patients and 5.1% (95% CI: 3.9%, 8.4%) in urology patients.

The incidence of specific types of infection also varied. Urinary tract infections (UTIs) were the most frequent type of infection accounting for 48.1% of infections identified; surgical wound infections (SWIs) accounted for 19.2%; lower respiratory tract infections (LRTIs) 11.1%; skin infections 7.7%; bloodstream infections (BSIs) 1.9%; and infections at other sites 12.1%.

Valid comparisons of the incidence rate observed in this study with those observed in other studies are difficult. Important differences exist between this and other studies with respect to the definitions used, surveillance methods employed, the case-mix studied and the treatment patterns followed in the different clinical settings. As discussed in Chapter 2 these differences will inevitably influence the reported incidence rates. Inability to control for these differences renders meaningful, valid comparisons difficult. A study conducted in a similar type of NHS hospital in England in 1992, using the same definitions and surveillance methods used in this study, observed a higher incidence rate amongst surgical patients than that observed in this study: 9.7% of in-patients admitted to the general surgical, gynaecology and orthopaedic specialties of an NHS hospital acquired and presented with an infection whilst in hospital.[47] Without further details about the case mix and treatment patterns present it is difficult to interpret these findings. The different infection rates could reflect differences in practice, with the study hospital performing better with respect to infection control. Alternatively they could reflect important case-mix differences, with the study hospital treating patients at lower risk of infection than patients involved in the study by Glenister *et al* (1992).[47] The most likely explanation is that there was a combination of factors at play.

Whilst precise comparisons of the incidence rates observed in the various studies cannot be made, it is interesting to note that studies have found similar patterns with respect to the frequency of the different types of HAI. As in this study, other incidence studies have reported UTIs, SWIs, and LRTIs be the most frequent types of HAI with UTIs being the most frequent.[48 47]

11.2.2 Risk factors for HAI

The results of the multivariable logistic regression analysis indicated that the odds of acquiring an HAI were higher in females than males; increased with increasing age category and increasing number of co-morbidities; were higher in patients who had diabetes mellitus listed as a co-morbidity; were higher in emergency as compared to elective admissions; varied with admission specialty being highest in gynaecology patients; were greater in patients who had received antibiotics prior to the onset of an infection; and were higher in patients who had one or more operations. With the exception of sex, and diabetic status, the variation identified above was significant at the 5% level. The results of a separate analysis limited to 1,588 patients for whom data on body mass index (BMI) were available found that the incidence did not vary significantly with BMI.

11.2.2.1 Urinary tract infections

The results of the multivariable logistic regression analysis, undertaken to assess independent risk factors for UTIs, indicated that female patients and patients who had been catheterised prior to the onset of this type of infection were at greater risk of acquiring a UTI than male and non-catheterised patients. The odds of acquiring a UTI were 2.6 (95% CI: 1.6, 4.1) times higher in catheterised patients compared to non-catheterised patients and 2.8 (95% CI: 1.4, 5.6) times higher in female compared to male patients. The odds of acquiring a UTI were also found to increase with increasing age category, and varied significantly with admission specialty. The odds of acquiring a UTI were higher for gynaecology and obstetric patients, compared to patients in the other specialty groups and were higher in patients who had an operative procedure (Odds ratio 1.1 95% CI: 1.1, 6.5). The odds increased with increasing number of co-morbidities, and were higher in patients who had diabetes mellitus listed as a co-morbidity, however these increases were not significant at the 5% level. Similarly whilst the odds of acquiring a UTI were higher for emergency patients, this was not found to be significant at the 5% level. The odds of acquiring a UTI were similar both in patients who had antibiotics prior to a UTI and in those who

had not, although the upper confidence intervals suggest that in some case patients who received prophylactic antibiotics were at greater risk of acquiring a UTI. This outcome suggests that the administration of prophylactic antibiotics is perhaps a marker for another risk factor not included in this model.

11.2.2.2 Surgical wound infections

The results of the multivariable logistic regression analysis undertaken to assess independent risk factors for SWIs identified just one independent risk factor that was significantly associated with the risk of acquiring a SWI at the 5% level. The presence of one or more wound drains was found to increase the risk of acquiring this type of infection by a factor of 2.2:1 (95% CI:1.0, 5.0).

11.2.2.3 Lower respiratory tract infections

The results of the multivariable logistic regression analysis undertaken to assess independent risk factors for LRTIs also identified just one factor that was significant at the 5% level. The presence of an endotracheal or tracheostomy tube was found to increase the risk of acquiring a LRTI by a factor of 77:1 (95% CI: 27.4, 216.9).

To a degree the results of this study are consistent with the findings of earlier studies. For example, a number of earlier studies have identified urinary catheters and female sex to be key risk factors for UTIs,[1 134 137 138 143 144] whilst others have identified the presence of an endotracheal or tracheostomy tube as key risk factors for lower respiratory tract infections.[1 147] However, unlike some earlier studies, this study did not find a significant associated between diabetes mellitus and infection or a significant association between body mass index and infection risk.[19 66 74 138 141 142] However, it should be noted that only 3.4% of patients studied had diabetes mellitus and data on BMI was only available for 63% of the patients studied, thus limiting the ability of this work to identify an association if present.

11.2.3 Economic burden

Generalised linear modelling statistical techniques were used to determine how much of the observed variation in costs and LOS could be attributed to the presence of an infection. The analysis controlled for the potentially confounding effects of age, sex, number of co-morbidities, admission type, and admission specialty and used both an identity and a log link. Models that incorporate an identity link assume additive effects, and as such its use enabled estimates of the mean additional costs incurred by infected patients, and the mean number of additional days infected patients remained in hospital, to be taken directly from the model. In contrast models incorporating a log link assume multiplicative or proportional effects, thus providing estimates of the ratio of costs and LOS incurred by infected compared to uninfected patients.

It is not clear which approach most accurately reflects the impact of HAI on costs and LOS. Whether HAIs on average have an additive or a proportional effect will to some extent vary with specialty and type of infection. Consequently, since it is impossible to establish that either is the correct way to assess the impact of HAI on costs, estimates of both the average costs of HAI and the average proportional increase in costs incurred by infected compared to uninfected patients, after controlling for a number of potential confounding factors, have been reported in this thesis. However, it is worth noting that the ratios of the costs incurred by infected compared to uninfected patients, derived from the additional cost estimates, taken from the identity link model, are very similar to the ratios obtained directly from the model using a log link and vice-versa.

11.2.3.1 Estimated cost to the hospital sector as a result of additional in-patient care

The results indicate that acquiring an infection, on average, increased hospital costs by a factor of 2.3 (95% CI: 2.0, 2.6). Estimates of the additional costs attributable to infection indicated that on average HAIs cost the hospital sector an additional £2,254 (95% CI: £1,738, £2,770) per case.

Estimates of the impact of HAI on hospital costs were found to vary with specialty. Estimates of the proportional increase in hospital costs incurred by infected compared to uninfected patients from the same specialty indicated that infections occurring in general surgical patients, on average, increased costs by a factor of 3.9 (95% CI: 3.0, 4.9), whereas infections occurring in orthopaedic patients were estimated to increase costs by a factor of 2.4 (95% CI: 1.8, 3.3); in urology patients costs were estimated to increase by a factor of 2.1 (95% CI: 1.5, 2.9); in gynaecology patients costs were estimated to increase by a factor of 1.2 (95% CI: 0.9, 1.6); and in patients who had a caesarean section, costs were estimated to increase by a factor of 1.1 (95% CI: 0.7, 1.6). As evidenced by the confidence intervals, there was some uncertainty about the estimates relating to both obstetric and gynaecology patients.

Estimates of the additional costs incurred, indicated that on average HAIs occurring in general surgical patients cost the hospital sector an additional £4,368 (95% CI: £2,992, £5,744) per case; this compared to an additional £3,357 (95% CI: £1,821, £4,894) per case in orthopaedic patients; an additional £1,474 (95% CI: £534, £2,414) per case in urology patients; an additional £375 (95% CI:-£145, £895) per case in gynaecology patients and an additional £207 (95% CI:-£841, £121) per case in patients who had undergone a caesarean section. Again, as shown by the confidence intervals, there was some uncertainty about the estimates relating to both obstetric and gynaecology patients.

Cost estimates also varied with site of infection. The results indicated that multiple infections were the most costly and that UTIs were the least costly. The acquisition of more than one HAI was estimated to result in hospital costs almost six times higher than uninfected patients (model estimate: 5.8 95% CI: 3.9, 7.9). In contrast, UTIs, on average, were estimated to increase costs by a factor of just 1.6 (95% CI: 1.3, 1.9). With the exception of BSIs, infections occurring at the other sites were estimated to result in a two to three fold increase in costs. Acquisition of a BSI and no other infection was estimated to

increase costs by a factor of 6.0 (95% CI: 2.2, 16.2). However, as evidenced by the confidence interval there was considerable uncertainty about this estimate. Only three patients acquired a BSI and no other infection, two of whom died as in-patients.

Estimates of the additional costs incurred indicated that on average, multiple infections cost the hospital sector an additional £8,118 (95%CI: £7,930, £11,310) per case, whereas UTIs, on average, were estimated to cost £944 (95% CI: £441, £1,446) per case. The average cost of infections occurring at other sites were as follows: SWIs £1,497 (95% CI: £548, £2,447); infections at sites not elsewhere classified £1,671 (95% CI: £279, £3,064); skin infections £1,567 (95% CI: -£110, £3,245); LRTIs £2,672 (95% CI: £753, £4,592) and BSIs £6,953 (95% CI: -£1,652, £15,558).

The estimates derived in this study are considerably higher than those derived in other studies. For example, the most recent UK based study that estimated the economic burden of HAIs occurring in surgical patients (general surgical, gynaecology and orthopaedic patients), indicated that on average HAIs costs the hospital sector £1,041 per case.[14]

A number of factors could account for the higher cost estimate derived in this study. Firstly the infections identified in this study may have been more resource intensive and thus more costly to treat. However, this is unlikely to explain all the cost differences observed. Other factors which might in part explain the considerable difference in the estimates derived in this study, and those reported in the study by Coello *et al* include inflation (the study by Coello *et al* was conducted in 1988), the more detailed approach to identifying and valuing resources used in this study, and differences with respect to the attribution methods employed which in turn could impact on the estimates derived.

Whilst the precise estimates derived in earlier studies differ markedly to those obtained in this study, the pattern of increase is similar. For example, as in this study, Coello *et a* [14] found UTIs to be the least costly infections and multiple infections the most resource intensive. A number of other studies that have examined the relative costs of different types of HAI have also found UTIs to be the least resource intensive.[171 11 69]

11.2.3.2 Estimated number of additional days infected patients remain in hospital

HAIs were, on average, estimated to increase the patients LOS by a factor of 2.1 (95% CI: 1.8, 2.5). Estimates of the number of extra days patients remained in hospital indicated that on average HAIs extended the in-patient stay by 7.8 days (95% CI: 5.7 to 10.0).

As with costs, the estimates of the number of extra days patients remained in hospital varied with specialty. Infections occurring in general surgical patients were estimated to result in a three fold increase in LOS (model estimate 3.4, 95% CI: 2.6, 4.4), whereas infections occurring in orthopaedic and urology patients, on average, were estimated to double the in-patient stay. HAIs occurring in orthopaedic patients were estimated to increase the LOS by a factor of 2.0 (95% CI: 1.4, 2.7) and in urology patients by a factor of 2.5 (95% CI: 1.7, 3.6). Infections occurring in gynaecology and obstetric patients were estimated to have a relatively small impact on LOS. HAIs occurring in gynaecology patients were estimated to increase the LOS by a factor of 1.3 (95% CI: 1.0, 1.7) and infections occurring in obstetric patients were estimated to increase LOS by a factor of 1.1 (95% CI: 0.7, 1.6).

Estimates of the number of extra days attributable to HAI indicated that, on average, infections occurring in general surgical patients prolonged the in-patient stay by 15.3 (95% CI: 9.5, 21.0) days, whereas HAIs occurring in orthopaedic patients were estimated to extend the LOS by 11.7 (95% CI: 4.7, 18.8) days; in urology patients by 7.9 (95% CI: 2.9,12.9) days, in gynaecology

patients by 1.8 (95% CI:-0.4, 4.0) days and in patients who had undergone a caesarean section LOS, on average, was extended by 0.6 (95% CI:-2.8, 4.1) days. As with costs, as shown by the confidence intervals obtained, there was considerable uncertainty about the estimates of the number of additional days infected obstetric and gynaecology patients remained in hospital.

Estimates of the impact HAI had on LOS also varied with site of infection. The results indicated that acquiring more than one infection resulted in the greatest proportional increase in LOS: on average, multiple infections were estimated to increase LOS by a factor of 4.4 (95% CI: 2.9, 6.5). In contrast BSIs were estimated to increase LOS by a factor of just 1.5 (95% CI: 0.5, 4.4). This might appear a rather surprising finding. However, as mentioned above only three patients acquired a BSI and no other infection, two of whom died whilst in hospital thus curtailing their length of hospital stay. As shown by the confidence interval, there was considerable uncertainty around this estimate. It is interesting to note that whilst the LOS of patients who acquired a BSI and no other infection was not markedly prolonged, as mentioned in section 11.2.3.1 the costs incurred were considerable. On average, acquiring a BSI was estimated to result in a six-fold (95% CI: 2.2, 16.2) increase in costs. Whilst, as evidenced by the wide confidence intervals, there was some uncertainty surrounding this estimate, the results suggest that whilst LOS is not markedly increased costs are, thus indicating that the time in hospital is resource intensive.

Acquisition of a UTI was also found to have a relatively small impact on LOS. UTIs were estimated to extend the LOS by a factor of 1.5 (95% CI: 1.3, 1.9). Infections occurring at the other sites on average were estimated to result in a two fold increase in LOS.

Site-specific estimates of the number of extra days patients remained in hospital indicated that, on average, multiple infections extended the in-patient stay by 24 days (95% CI:11.8, 36.4), whereas BSIs and no other infection were estimated

to extend the in-patient stay by just 2.2 (95% CI: -7.1, 11.5) days. UTIs were estimated to prolong the in-patient stay by 3.3 (95% CI: 1.3, 5.3) days, SWIs were estimated to extended the LOS by 7.2 (95% CI: 2.3, 12.0) days, LRTIs by 8.0 (95% 0.6, 15.4) days; skin infections by 9.9 (95% CI: 0.4, 19.3) days, and infections at sites not elsewhere classified by 11.6 (95%CI: 3.0, 20.2) days.

11.2.3.3 Distribution of additional costs

This study took a detailed approach to assessing the cost of resources used by both infected and uninfected patients. The resources used were categorised under a number of headings (hospital overheads, directorate management, capital charges, medical time, nursing care, paramedics and specialist nurses, physiotherapy, surgical interventions, consumables used for specific procedures, antimicrobials, non-antimicrobial drugs, microbiology tests, other pathology tests, endoscopies, radiology and other tests) and the distribution of the additional costs incurred by infected patients subsequently assessed. The results indicated that for all cost categories, the costs incurred by infected patients were higher than for uninfected patients. The cost of nursing care was the largest contributor to the additional costs incurred accounting for 40.5% of the additional costs. Cost categories that were directly linked to time in hospital, taken together, were the second largest contributor accounting for 38.4% of the additional costs incurred by infected patients. Costs that were considered to be directly linked to time in hospital included the costs of hospital overheads, directorate management, capital charges and medical time. These costs were all assigned to individual patients on the basis of their LOS.

The distribution of costs varied with site of infection reflecting the different resource requirements of different types of HAI. For example, nursing care accounted for a varying proportion of the costs attributed to infection. Nursing care accounted for 60% of the cost of BSIs; 46% of the costs of multiple infections and LRTIs; 34% of the cost of UTIs, 33% of cost of SWIs, just 25% of the cost of skin infections and 28% of the costs associated with infections at a range of other sites.

11.3 Strengths of study

11.3.1 Inclusion of a number of surgical specialties

One of the strengths of this study was that it assessed the incidence and economic burden of HAIs occurring in adult, non-day case patients admitted to surgical specialties common to all district general hospitals: general surgery, orthopaedics, urology, gynaecology and obstetrics (caesarean sections only). Nationally patients admitted to these specialties accounted for 35% of all adult non-day case admissions in 1994/5.[221] The results of this study are therefore relevant to a substantial proportion of NHS patients.

This study provides important data on the incidence of, and risk factors for HAIs occurring in adult non-day case patients admitted to the specialties listed above and the economic burden they impose on the hospital sector. Few studies have assessed the incidence of HAI occurring in such a broad case mix of patients. Three notable exceptions are the SENIC study conducted in the US in 1975 which assessed the incidence of HAI occurring in 6,449 medical and surgical patients;[49] a study by Glenister *et al*[47] which assessed the incidence of HAI occurring in 3,326 adult medical, surgical, orthopaedic and gynaecology patients; and an audit study involving 81,218 adult patients admitted to the medical, surgical, orthopaedic and gynaecology specialties of 19 hospitals in England and Wales conducted in 1993/4.[1] The majority of incidence studies have focussed on the incidence of HAIs occurring in a narrower group of patients defined by specialty or operative procedure. For example, a number of studies have focussed on the incidence of HAIs occurring in patients who had a caesarean section.[51-56]

Studies that have assessed the economic burden of HAI also vary in scope. Many studies are limited to the economic burden of HAIs occurring in patients admitted to a particular specialty or the burden associated with a particular type of infection occurring in a selected patient group. The most recent UK study that involved a broad case-mix of patients was a study in 1988 by Coello *et al* (1993)[14] that assessed the economic burden of HAIs occurring in adult patients

admitted to a similar range of specialties: general surgery, orthopaedics and gynaecology. The results reported in this thesis provide a more timely assessment of costs resulting from infections occurring in adult patients admitted to specialties common to most hospitals.

11.3.2 Use of previously validated definitions of infection and surveillance methods

The study used previously validated definitions of infection and surveillance methods thus enhancing the validity of the results obtained. The definitions and surveillance methods used were developed and validated in an earlier study by Glenister *et al* (1992).[77] The surveillance method adopted involved reviewing patient records (patient notes, drug charts, observations charts and microbiology records) and liaising with ward staff to identify signs and symptoms that were indicative of a possible infection. Those patients who had signs and symptoms that met the criteria for infection as detailed in the validated definitions were classified as having an infection.

11.3.3 A detailed approach to costing resource use

In marked contrast to other studies this study took a very detailed approach to the estimation of the economic burden HAIs place on the hospital sector as a result of additional in-patient care. Studies reported in the literature have generally limited their assessment of costs to a few areas considered to be directly linked to infection. For example, some studies have limited their assessment of costs to those associated with an extended length of stay, whilst others have adopted a slightly more detailed approach, including the cost of specific resources considered directly linked to infection such as the cost of antibiotics, in addition to those costs associated with an extended stay.[13 14 189]

In this study no assumptions were made as to what types of resources might be used in greater quantity by infected patients as a consequence of having acquired an infection in hospital. As far as possible data on all resources used by both infected and uninfected patients were collected and subsequently

valued. This included the costs of all drugs prescribed, investigations undertaken, procedures performed, care administered by nurses, doctors and personnel from the professions allied to medicine, and the costs associated with an extended hospital stay. Estimates of the value of these resources were subsequently made and statistical modelling techniques employed to determine how much of the observed variation in costs between infected and uninfected patients could be attributed to the presence of an HAI.

The methods derived to estimate the value of these resources were also very detailed. Earlier studies have tended to value resources by applying an average cost to the resources used. For example, in many cases estimates of the cost of an extended hospital stay have been derived by first deriving an estimate of the average cost per bed day and then applying this to the number of extra days infected patients were estimated to remain in hospital. Such an approach fails to take into account that costs may vary markedly with day of admission. Hollingsworth *et al* (1993) found that patients admitted to hospital with a fractured neck of femur incurred relatively high daily costs during the first few days in hospital, after which they decreased.[198] Similar patterns are likely to be present for other types of patients undergoing emergency surgery, whereas for elective patients, depending on the day of surgery, costs may initially be relatively low on admission to hospital, rising on the day of surgery, and then decreasing over time as the patient recovers and becomes less dependent on nursing and medical care. The use of an average cost also fails to take into account that complications such as an infection may cause daily costs to increase, the level of increase depending on the type and severity of the infection and how it interacts with the patients other co-morbidities.

In this study, detailed data were collected on the types and quantities of resources used. As such, wherever possible, the estimates of the cost of resources used reflect consumption by individual patients. Unit costs were derived for laboratory and radiology tests, drugs, operations and procedures performed, and subsequently allocated to individual patients based on the

amount consumed. The methods developed to derive unit costs aimed to take into account all resources used. For example, the cost of administering an intramuscular drug not only included the cost of the drug, but also the cost of the syringe, needle and, if applicable the cost of the solution used in the preparation of the drug for administration. The cost of the time and skills involved in preparing the drug and subsequently administering it were included in the pharmacy overhead costs allocated on a cost per bed day, and the nursing care costs allocated on the basis of the amount of nursing care individual patients received on a daily basis. The algorithms used to derive nursing costs took into account the number and types of drugs administered on a daily basis.

As indicated above, estimates of the cost of nursing care took into account the level of nursing care administered to patients on a daily basis. Patients were categorised into one of seven nursing care groups based on the intensity of the nursing care received. Care group one denoted patients who needed very little nursing care, whereas at the other end of the spectrum, care group seven denoted patients requiring 24 hour nursing care. Using a previously validated care group weighting system, nursing care costs for individual wards were allocated to patients based on their daily care group.

Estimates of the costs of care administered by physiotherapists, occupational therapists, nutritionists and other health personnel from the professions allied to medicine, were derived from activity data and employment costs, and allocated on the basis of the number of contacts individual patients had with these health care professionals. Unfortunately it was not possible to adopt a similar approach for medical care. Resource constraints prohibited the assessment of the amount of care individual patients received from medical staff. As such an average cost per bed day was derived for medical costs and allocated to patients on the basis of the number of days they remained in hospital.

Similarly it was beyond the scope of this study to assess individual patient consumption of the services provided by the various overhead directorates. As such estimates of the cost of the hospital overheads were attributed to patients on the basis of an average cost per day, having first allowed for consumption of the various overhead directorates by the overheard directorates themselves. For example, the allocation model developed did not simply apportion the costs of heating to individual patients based on their LOS, but through the use of a series of simultaneous equations first allowed for consumption of heating by the 'Estates Directorate' itself and the other overhead directorates. Once this had been taken into account the remaining costs were allocated to patients on the basis of an average cost per day.

This detailed approach to identifying and estimating the cost of resources used by both infected and uninfected patients was both time consuming and complex to undertake. However, the approach offered a number of advantages over limiting estimates to the number and cost of extra days patients remained in hospital and the use and cost of a few specific resources considered to be linked to infection. The approach used enabled a more accurate assessment of the costs of resources used by individual patients, from which estimates of the ratio of costs and the additional costs incurred by infected compared to uninfected patients could be derived. Since the methods employed did not make any assumptions as to what categories of costs were likely to be higher in infected than uninfected patients, the approach enabled a detailed assessment of the distribution of additional costs to be made, thus providing information which may be of use to those involved in decision making regarding the allocation and use of scarce hospital resources.

11.3.4 Attribution methods

As discussed in Chapter 3, the majority of studies that have assessed the economic burden of HAI have adopted one of three methods to attribute resource use and costs to infection: the concurrent method which involves the subjective assessment of the resources used by infected patients as a result of

their infection, the comparative method, and the comparative method with matching of cases and controls. As detailed in Chapter 3 all three approaches have their limitations.

In this study an alternative approach to the attribution of resource use and costs to HAI was taken. A large cohort of patients was followed and patients who acquired an infection in hospital identified. Generalised linear modelling statistical techniques were then used to assess the impact of HAI on hospital resource use and costs by comparison of the HAI group and remainder of the cohort. The modelling took into account a range of factors that, in addition to the presence of an HAI, were considered to influence resource use and costs (age, sex, admission specialty, admission type, and number of co-morbidities). Two methods of describing the impact of HAI on resource use were used. Estimates of the proportional increase in costs and LOS incurred by infected patients compared to uninfected patients were derived through the use of a log link, and estimates of the additional costs and extra days in hospital attributable to HAI were derived through the use of an identity link.

This alternative approach to attribution has a number of strengths. The approach is considerably more rigorous that the concurrent approach, the validity and reliability of which has been questioned in the literature.[187] It has been suggested that physician reviewers may be hesitant to attribute resources to the presence of an HAI and as such the resulting estimates of costs may be underestimates of the resources and costs that are attributable to the presence of an infection.[48] The approach adopted in this study did not involve subjective assessment of resources used by infected patients. The resources used by both infected and uninfected patients were identified and costed and generalised linear modelling statistical techniques applied to determine how much of the observed variation in resource use and costs could be attributed to infection.

This approach also has a number of strengths when compared to the comparative approach. The comparative approach without matching simply involves assessing resource use and costs incurred by infected and uninfected patients and attributing any cost differences to the presence of an infection. The approach does not take into account any other factors that might differ between the two groups of patients (infected and uninfected) that in turn might influence resource use and costs. For example, infected patients even in the absence of an infection may have utilised more resources than uninfected patients and as such only a proportion of the additional costs incurred can be justly attributed to the infection. Thus failure to control for important differences between infected and uninfected patients that in turn might influence resource use and costs, may result in an overestimate of the economic burden of HAI. Haley *et al* (1980) compared three alternative methods for the attribution of resources and costs to HAI and concluded that studies which attributed resource use and costs to HAI using the comparative approach resulted in overestimates of the costs attributable to infection.[48] The analysis used in this study controlled for a number of factors that might influence resource use and costs.

The comparative approach with matching of cases and controls does take into account factors that may influence resource use and costs. Infected patients are matched with controls on the basis of factors such as age, sex, diagnosis and number of co-morbidities. However, studies frequently encounter difficulties finding suitable controls for infected patients, resulting in infected patients being lost from the final analysis. As detailed in Chapter 3, the proportion of infected patients for whom suitable controls can be found varies considerably with study. Haley *et al* (1980)[48] in a review of matched studies conducted between 1953 and 1975, found the proportion of infected patients who were successfully matched with uninfected 'controls' varied considerably from a low of 32% to 100%. Scheckler *et al* (1978)[171] in a study to assess the economic burden of HAIs occurring in 104 patients admitted to a community hospital in the US between January and March 1978 were unable to find a

sufficient number of suitable controls and therefore had to abandon this approach to attribution of costs. A more recent study, conducted in the UK, successfully matched 67 (85%) of the 79 infected surgical patients for whom medical records were available for review.[14] A study by Kappstein *et al* (1992),[182] which assessed the excess costs and LOS resulting from ventilator associated pneumonia occurring in patients admitted to the intensive care unit of a university teaching hospital in Germany, found that after excluding cases that died during their admission, suitable controls could only be found for 34 (60%) of the 57 cases, and a study conducted in Turkey in 1994 involving general surgical patients successfully matched only 67% of their 225 infected patients.[61]

In those cases where suitable controls are found this approach provides valuable estimates of the economic burden imposed. However, the estimates derived represent the economic burden imposed by infections occurring in a limited set of patients. Frequently it is the sicker, more resource intensive patients for whom suitable controls cannot be found. Thus the estimates derived may underestimate the average costs of HAIs occurring in the wider population from which the infected patients were identified. The strength of the approach adopted in this study was that it included all infected patients. By utilising all the available data it was possible to control for a similar range of factors as have been used in comparative-with-matching studies, yet include all infected patients. As such a broader understanding of the average costs of infections occurring in surgical patients was derived. Whilst some of the infections may have imposed a relatively small burden and others may have been considerable more expensive, the approach allows for an overall average estimate to be derived.

11.3.5 Generalisability of results to other health care settings

A major strength of this work is the perceived generalisability of the results to other health care settings. The results of this study were derived from data relating to adult non-day case patients admitted to five surgical specialties of

one NHS hospital in England. The inclusion of just one hospital inevitably represents a limitation of the study design. Ideally patients would have been recruited from a number of hospitals randomly selected, however funding constraints prohibited the inclusion of more than one hospital site. However, despite this limitation for a number of reasons it would appear justifiable to assume that the results may be taken to represent what occurs in patients admitted to the same clinical specialties in other health care settings.

The hospital selected was an NHS district general hospital not dissimilar to other district general hospitals in England in terms of the types of care offered, its size, and a range of financial indicators[2] and, as already mentioned, patients were selected from specialties common to all district general hospitals. It is acknowledged that the cost of resources will inevitably vary to some extent from one hospital to another, depending on a number of factors such as the suppliers to the hospital. However, the cost of specific resources within any given setting will be the same for both infected and uninfected patients. As such, if it can be assumed that clinical practice at the study hospital is similar to that occurring in other health care facilities, it is likely that the ratios of costs incurred by infected compared to uninfected patients derived from the statistical analysis, reflect those occurring in adult non-day case patients admitted to the same specialties at other NHS hospitals. Additionally, since the study hospital was not dissimilar to other district general hospitals it is also likely that the estimates of the additional costs of HAIs are also broadly generalisable to other health care settings.

If it is accepted that the results are generalisable to other settings this represents a major strength of the study design facilitating the wider application and use of the study results. For example, they can be used in economic models to assess the burden of HAI occurring in a specified population of patients from similar specialties, and when used together with data on the cost and effectiveness of infection control practices, the results can be used to estimate the potential benefits of investment in infection control. Predictive

models can be developed and the results of such models can subsequently contribute towards decisions about the allocation of resources to infection prevention and control and the nature of infection control programmes.

11.4 Limitations

Whilst recognising the strengths of the study, the results should be interpreted in the context of the limitations of the methods used. These limitations relate to a number of factors that are discussed below.

11.4.1 The study was limited to one hospital

As acknowledged above in section 11.3.5 the study was limited to one hospital. Inevitably this potentially has implications for the generalisabily of the results. Ideally a number of randomly selected hospitals would have been included allowing for inter-hospital comparisons to be made and the generalisability of the main results to be assessed. Resource constraints prohibited such an approach. Nevertheless it should be noted that the hospital selected was not dissimilar to other district general hospitals in England and as such, whilst the inclusion of a number of hospitals would have been preferable, the limitations of just one study site are not as marked as they might have been.

11.4.2 Limited to adult non–day case patients admitted to selected surgical specialties

The estimates derived in this study reflect the incidence and economic burden of HAIs occurring in adult non-day case patients admitted to five surgical specialties of a district general hospital. The burden imposed by infections occurring in excluded patient groups may differ from these estimates. In some cases the costs may be considerably higher than those estimated here. For example, the cost of HAIs occurring in patients who have received cardiac surgery may be considerably higher. Other excluded groups include neonates; paediatrics; day cases; and patients admitted to burns, oncology, dialysis, and neurosurgical units. Whilst focussing on this patient group represents a limitation of the study, it should be noted that the specialties included are

common to most NHS hospitals and that patients admitted to these specialties account for a substantial proportion of NHS admissions. In 1994/5 patients admitted to the five surgical specialties covered in this study accounted for 35% of all adult non-day case admissions.[221]

11.4.3 Potential patient selection bias

Selection bias occurs if patients successfully recruited into the study are systematically different from those who were not recruited.[246] In this study failure to invite all eligible patients to participate in the study and patient refusal are two areas that potentially may have introduced some bias.

As far as possible the research assistants attempted to invite all eligible patients (i.e. patients who met the inclusion criteria) to participate in the study. However, for a number of practical reasons this was not always possible. Time constraints were a key limiting factor. The research assistants were required to collect a vast amount of data on each patient successfully recruited into the study. In order to ensure a complete data set was obtained for all those recruited it was not possible to attempt to recruit all eligible patients. Another constraint was that at times it was not possible to identify a suitable time to approach eligible patients and invite them to participate.

Failure to recruit all eligible patients is not in itself a problem, providing that the cohort of patients not invited to participate, are similar to those who were invited to participate. However, the risk is that those patients not invited to participate in the study differ from those invited in some important respect. For example due to time pressures it is possible that the research assistants may have consciously, or subconsciously, elected to recruit patients who were perhaps not as acutely ill, in preference to those who were acutely ill. Such patients are likely to have been easier to recruit and, following recruitment may have resulted in less data collection that the sicker patients. Furthermore, it is likely that the less acutely ill patients are more readily available for recruitment than those who are acutely ill. Many of the sicker patients may have been engaged

with medical and nursing staff when the research assistants were trying to recruit patients, thus prohibiting recruitment at that time. However, it should be noted that if these and/or other differences were present they are not likely to have major implications unless the differences are unequally distributed between infected and uninfected patient groups. If those patients who were not invited to participate in the study differed in important respects to those who were invited, and these differences were concentrated in what would have been the 'infected' or the 'uninfected' patient group had they been recruited, failure to recruit all eligible patients will have implications for the representativeness of the results. However, if these differences are equally distributed between the intended 'infected' and 'uninfected' patient groups had all eligible patients been recruited, the implications for the representativeness of the results obtained are likely to be minimal.

It is possible that many of the anticipated differences between patients invited to participate in the study and those not invited may have had impact on the level of resource use and in turn may have been unequally distributed between infected and uninfected patients. For example, it is possible that patients who were acutely ill on admission, may in some cases have utilised more resources than the less acutely ill, and may also have been at greater risk of infection. Had they been recruited these patients may have been concentrated in what would have been the 'infected' group. Consequently, failure to recruit these patients may have introduced bias into the results obtained.

Refusal to participate in the study may also have introduced some bias. Overall 5.6% of patients refused to participate. Their reasons for doing so varied. Some patients had an inherent distrust of research studies and simply did not want to be involved. Others were concerned about the time implications for themselves as participants (the underlying study required a proportion of patients to complete a post-discharge questionnaire). Again if differences were present and these were unequally distributed between what would have been the 'infected' and 'uninfected' patient groups, then this again would have introduced some bias into the results.

A number of steps were taken to minimise and monitor this risk of selection bias. The importance of minimising this risk was discussed with the research assistants prior to the start of data collection; appropriate recruitment training was given and the research assistants were required to record base line data on those patient they were unable to recruit. This included details of age group, admission specialty and type of admission. The age group, admission specialty and admission type distributions of recruited patients and eligible patients who for practical reasons were not invited to participate and patients who refused participation were subsequently compared. Whilst some differences were observed, these were not marked. As such it can be concluded that on the basis of these factors the recruited sample was fairly representative of the wider eligible population group at the study hospital. However it is possible that there may be other systematic differences between those invited to participate and those who were not invited or refused participation, which are not accounted for in this analysis.

11.4.4 Limited to the assessment of the incidence of HAIs presenting during the in-patient period

This thesis was limited to the estimation of the incidence of HAIs presenting during the in-patient period. Infections acquired in hospital but presenting following discharge were not included. As such the results presented are inevitably an underestimate of the 'true' incidence of HAI. The results of the study to which this work is linked suggest that infections presenting in the community are a considerable problem.[2] The study found that 19% of patients who, at the time of discharge were classified as not having an infection, reported signs and symptoms suggestive of an infection occurring within four weeks of discharge from hospital. Of those patients who had an infection identified in hospital 30% reported signs and symptoms suggestive of an infection occurring within four weeks of discharge. It was not clear whether these infections represented a new problem or a continuation of the infection first identified in hospital. Other studies have also highlighted this problem.

Studies examining the incidence of SWIs presenting post-discharge indicate that anything from 20 -86% of SWIs present post-discharge.[98 99 65 100-102 247 57 74 103-105]

When considering the magnitude of the problem of HAI the fact that the incidence of HAI observed in this study was limited to infections presenting during the in patient period and that more infections may have presented post-discharge should be borne in mind.

11.4.5 Strict criteria for identifying surgical wound infections

As indicated above in section 11.3.2 one of the strengths of this study was the use of previously validated definitions of infection. However, it should be noted that the definition for SWI was rather strict. The definition used stated that there needed to be a purulent discharge from the wound plus or minus a range of symptoms. Whilst this definition probably ensured that there were few false positives, it also probably led to a number of false negatives and as such an under-estimation of the incidence of SWIs. The need for a purulent discharge to be present is likely to have resulted in a number of patients being misclassified as uninfected patients. The research assistants reported that in a number of cases patients who were pyrexial, and had a red and inflamed wound area were treated as if they had an infection with initiation of antibiotic therapy. The surgical team did not wait for a purulent discharge to develop before prescribing antibiotics. This was particularly noticeable amongst orthopaedic patients where the consequences of an infected wound can be particularly severe. For example, a SWI following a total hip replacement could quickly develop into an infected prosthesis requiring revision of the hip replacement. Thus, as indicated above, the research assistants reported that antibiotics were frequently prescribed prior to the development of purulent discharge. Consequently, the incidence of SWI in this study is likely to be an underestimate of the 'true' incidence of this type of infection, and as such the overall estimate of the incidence of HAI is also likely to be an underestimate. The cost estimates may also be underestimated. If a proportion of infected patients were misclassified as uninfected, and resource use amongst these incorrectly

classified patients was higher than uninfected patients, then the effect would have been to increase the average cost of uninfected patients and reduce the ratio of increase in costs amongst infected patients and the estimates of the additional costs incurred.

11.4.6 Incomplete data on the pathogens involved.

The results of the underlying study indicated that data on pathogens involved were only available for 50% of infections identified.[2] Given the paucity of data, it was realised at the outset that an analysis of the impact infections involving specific pathogens or groups of pathogens had on hospital costs was likely to be beyond the scope of this thesis. This was borne out by the data: less that 50% of infections occurring in surgical patients had a pathogen identified. The study's inability to estimate the incidence of specific types of infection defined by causative pathogen, and the impact they have on resources used, represents a limitation of this study, and is an area requiring further study. It is likely that the cost of infections will vary depending on the pathogen involved, with the greatest costs resulting from infections involving antibiotic resistant pathogens. If this is considered to be the case, future work should perhaps focus on this.

11.4.7 Incomplete data on risk factors for HAI

This study is linked to a wider study of the socio-economic burden of HAI in adult non-day case patients admitted to both medical and surgical specialties of a district general hospital. The underlying study, was primarily concerned with the economic burden infections imposed, and not the identification of risk factors for these infections. However, at the outset it was acknowledged that if possible it would be desirable to collect data on risk factors for HAIs. At the same time, the need not to over burden the research nurses with excessive data collection requirements was appreciated. However, since the decision was taken to adopt a very detailed approach to identifying and costing resources used by infected and uninfected patients, it transpired that the planned collection of data on resource use also represented data on risk factors. For

example, data on the use of intravenous lines and urinary catheters not only provided data on the resources used but also the presence of two important risk factors for HAI. Similarly data on case-mix (age, sex, diagnosis, number of co-morbidities), which was essential for the attribution process also provided important risk factor data. However, the collection of some of the planned data caused problems for the research assistants. The volume of data required was considerable and the availability of some of the data varied. Whilst the research assistants encountered few problems when collecting data on case-mix, and key items of resource use (e.g. catheters and drains), problems were encountered when collecting operation data. The collection of data on operations undertaken did not present any problems. However more detailed information such as the length of time on the operating table, the grade of the surgeon who performed the surgery, and the ASA grade proved more difficult to obtain. The research assistants were instructed to obtain this information from the operating directorates audit data collection form. During the first few months of the data collection period no major problems were encountered. The form was readily available and generally well completed. However, over time the availability and the completeness of these forms decreased. A change of management may in part have been responsible for this decline. At the outset the manager of the Operations Directorate had an active interest in the data recorded on these forms that was subsequently used for audit purposes. However, this interest declined following a change in management. The resulting effect was incomplete data for a number of variables, which in turn reduced the ability to conduct risk factor analysis.

As such, when considering the results of the analysis that examined how the incidence of HAI and specific types of HAI varied with selected risk factors, it should be borne in mind that the range of factors included in the analysis were out of necessity limited to those for which data had been collected in the underlying study and for which there were complete data sets. Incomplete data particularly affected the analysis examining how SWIs varied with selected factors. Ideally additional factors would have been included in the analysis such

as data on the time the patient was on the operating table, grade of surgeon and ASA score. Thus whilst the results clearly show how the incidence varied with the factors included in the analysis, there may be other factors not included in the analysis which represent a more substantial risk factor for these infections.

11.4.8 The use of average costs

As detailed in section 11.3.3 this study adopted a very detailed approach to valuing resources used. As far as possible the costs allocated to individual patients reflect individual resource use. However, for some components of cost it was not possible to adopt such a detailed approach. For example, the cost of medical care did not reflect the actual amount of care administered to individual patients every day. An average cost per day was derived and allocated to patients on the basis of the number of days they remained in hospital. Resource constraints prohibited a more detailed approach. A more detailed approach to costing medical care, resulting in cost estimates which reflected the amount and type of medical care individual patients received on a daily basis would have required detailed time and motion studies: an approach that was beyond the scope of this study.

11.4.9 Attribution of resources used and costs to HAI

This study utilised statistical modelling techniques to assess how much of the observed variation in resource use and costs could be attributed to the presence of one or more HAIs. The strengths of this approach have been discussed in some detail above (section 11.3.4). In this section some of the limitations of the approach are described.

One of the immediate problems encountered is deciding what factors in addition to HAI status should be included in the analysis. The following were selected: age, sex, type of admission, admission specialty, and number of co-morbidities. These factors were considered to be influential in determining resource use. Single and multi-variable analysis indicated that total costs and LOS varied with

all these factors. However, whilst these variables were considered to be key, the possibility exists that there may be other factors that were excluded from this analysis which are better predictors of LOS and costs and this may have an impact on the estimates of the impact of HAI on total costs and LOS derived from the modelling analysis. However, unless these factors existed and influenced either the 'infected' or 'uninfected group' more than the other they will not have caused systematic biases.

11.4.10 The study was limited to the estimation of the costs to the hospital sector

This thesis has focussed on the economic burden HAIs place on the hospital sector as a result of additional in-patient treatment and care. No attempt has been made to assess the economic burden placed on the health sector (primary and secondary) post-discharge; on the patient concerned and their family and friends; or on the economy as a whole. These latter areas represent important cost centres. Focusing on the hospital alone inevitably can only provide a partial picture of the full costs that result from HAIs. In some cases patients identified as having acquired an infection, may be discharged from hospital and followed up in the community, imposing costs on the primary, and in some cases secondary, health care sector, if a greater number of out-patient visits than would have been the case in the absence of infection are required, or if the patient requires re-admission. Patients and carers may also experience increased costs. In other cases patients may not present with an HAI until after they have been discharged from hospital. Over recent years patient admissions have decreased in length, with patients discharged into the community at an earlier point in their recovery. Whilst in some respects this reduces the risk of acquiring an infection (the patient is not in hospital so long) it is not clear by how much the risk is reduced. The patient may have been exposed to many of the key risk factors during their short admission. In this study 29% of patients acquired an infection within the first four days of their admission and over 50% within the first six days. Consequently, it would appear that many of the major risks are encountered during the first few days. As such a policy of early

discharge may result in an increased likelihood of the infection presenting post-discharge. In such cases this may result in additional cost to the health sector in the community, and family and friends. In other cases, where costs are not increased, it may represent unmet need.

Estimation of the burden to these other areas was beyond the scope of this work. When considering the results of this work and their implication for the health service, costs falling on these other areas should be borne in mind.

11.4.11 The study was limited to the estimation of the economic burden of HAI

This study was primarily a cost of illness study and as such represents what Drummond refers to as a partial economic evaluation.[162] Estimation of the benefits of investing in activities that are directed towards preventing these infections was beyond the scope of this study. As such the results cannot be used to directly inform policy on the level of investment in infection control that should be made. However, the results do serve to highlight the magnitude of the burden these infections place on scarce hospital resources, and the gross benefits of prevention should these infections be prevented, in terms of the average value of resources that would be released if an infection was prevented. Furthermore, as detailed in Chapter 10 simple models can be developed from which estimates of the burden of HAI in a defined population, and the estimated gross benefits that would arise if a proportion were prevented, can be derived. More detailed models which utilise additional data on the cost and effectiveness of prevention activities, can subsequently be developed to estimate the net benefits of prevention. The results of such models can be used to inform and contribute to decision making regarding the allocation of resources to infection control and the nature of infection control programmes.

11.5 Methodological considerations

The methods employed in this study raised a number of practical difficulties, some of which are discussed in the following sections.

11.5.1 Recruitment

The recruitment of patients into this study presented a number of difficulties. Patients were recruited into the study by a research assistant, who adopted the following procedure. The research assistant would explain the study to the patient, ask the patient if they would be willing to participate in the study, and subsequently leave them with an information sheet and return at a convenient time to see if they were willing to participate. The main problem associated with this procedure was the fact that the research assistant had to introduce the topic of HAI at a time when frequently patients were anxious about their admission and proposed treatment. Many patients were unaware of the problem of HAI, and as such were rather alarmed to hear that whilst in hospital they might acquire an infection. This recruitment 'problem' was acknowledged at the outset and first experienced when conducting the pilot study. In order to overcome this and reduce the anxiety that patients may experience a number of steps were taken. Measures were taken to ensure that all ward staff and medical staff were aware of the study; posters were placed in all wards informing patients and relatives that a study was taking place; the study received some media coverage at its official launch, thus raising awareness of the issue; and the research assistants all received training in communication skills and recruitment procedures from myself and importantly from a trained communication expert. The aim was to equip the research assistants with the necessary skills to manage the recruitment process in a way that minimised anxiety yet kept patients informed of all relevant factors. It was important that all steps were taken to ensure that patients could make an informed choice about whether to participate in the study, whilst at the same time not causing undue anxiety and stress. These procedures appeared to be effective. Whilst it did not eliminate the difficulties associated with this procedure, the measures

were successful in helping and equipping the research assistants with the skills necessary to carry out this task.

11.5.2 Difficulties associated with conducting research in a clinical context

Conducting research in a clinical context presented a number of practical difficulties. These difficulties primarily related to the relationship between the patient and research assistant. All the research assistants were qualified nurses, a factor that whilst helping them to fulfil their role, also presented its own difficulties and conflicts.

As discussed in section 11.5.1 there were a number of difficulties associated with recruiting patients, in particular problems relating to raising the issue of the possibility that the patient might acquire an infection in hospital. The most recent UK prevalence study indicated that at any one time an estimated nine per cent of hospital in-patients have an infection that they acquired whilst in hospital.[7] For many patients this proved to be quite an alarming statistic.

In addition to these problems, there was the issue of confidentiality. Patients were assured that any information that they provided would be treated as confidential. A standards document was drafted which outlined procedures with respect to the handling and storage of patient data which all the research assistants and other members of the team were required to read and sign up to prior to the start of data collection (see Appendix 2). However, occasionally situations arose when a patient would tell the research assistant something directly relevant to their condition and circumstances, which ideally medical and nursing staff needed to know. This placed the research assistant in a difficult position. The research assistant was obliged to maintain the patients confidentiality. However, at the same time the research assistant was acutely aware of the need to inform nursing and medical staff. Such situations had to be handled with great care and sensitivity. In all cases the research assistant successfully persuaded the patient through reasoned discussion that they

should inform a member of medical or nursing staff. Additional training was given to the research assistants to help with situations such as these.

As indicated above the research assistants were all qualified nurses, a fact which undoubtedly helped them in their role. However, from their perspective, this often gave rise to conflict between their previous nursing role and their newly acquired research role. Support was given to help them to adapt to this different role, and develop boundaries that enabled them to fulfil the requirements of their research assistant role.

11.5.3 Quantity of data required.

The data requirements of this study were large. The research assistants were required to recruit patients into the study, obtain base line case-mix and demographic data, and then collect detailed data on the resources used by individual patients each day, whilst at the same time undertaking surveillance for all types of infection. In addition to this, although not related to the analysis presented in this thesis, they were also required to collect data from primary health care records. In order to collect this data successfully and ensure complete data sets, the research assistants were unable to recruit as many patients as they had wished. This trade off between data quality and number of patients recruited was discussed on many occasions. At all times the priority was to ensure full data sets.

11.6 Implications of results for policy

The results of this study have important implications for policy and practice. The results reinforce the findings of earlier studies that these infections affect a considerable number of people and place a substantial burden on scarce hospital resources. Whilst it is acknowledged that inclusion of just one hospital may be viewed as a limitation of the study design, for the reasons discussed in section 11.3.5 the results of this study are likely to adequately reflect the ratio of increase in resource use and costs incurred by infected compared to uninfected adult patients admitted to similar specialties within other NHS facilities, the

additional costs incurred and number of extra days infected patients remain in hospital, and to some extent the incidence of HAI.

The results of this study not only provide important data on the incidence of HAIs and the burden infections place on limited health sector resources, but also the gross benefits that might result if infections were prevented: that is the value of resources that might be released for alternative use if infections are prevented. Whilst not all HAIs are likely to be preventable, there being what Ayliffe[163] described as an 'irreducible minimum' it is clear that a proportion can be prevented. The results of a National Audit Office survey provide some insights into the proportion of infections that infection control teams consider could be prevented through improvements in infection control. The proportion of infections considered preventable varied between hospitals from a low of 5% to over 35%, with a bed weighted average of 15%.[3] The results presented in Chapter 10 indicate that if the results of this study are extrapolated to all adult non-day case patients admitted to the specialties covered in this study at the study hospital, it follows that a 15% reduction in rates would result in the prevention of 87 (95% CI: 75, 100) HAIs and the release of resources valued at £183,607 (95% CI: £134,761, £232,452) for alternative use. These released resources would include 646 (95% CI: 459, 834) bed days freed up for alternative use. Applying the results to a wider population of all adult non-day case patients admitted to similar specialties at other NHS hospitals throughout England in 1994/5, indicated that a 15% reduction in rates would result in the prevention of 23,238 (95% CI: 20,104, 26,691) HAIs and the release of resources valued at £49.17 million (95% CI: £36.09, £62.25 million) for alternative use. This estimate includes 173,059 (95% CI: 122,853, 223,265) bed days released for alternative use.

These results clearly demonstrate that prevention of infections would result in the release of considerable hospital resources for alternative use. These benefits may be considered to be the gross benefits of prevention, with net benefits dependent on the cost of achieving a reduction in rates. Estimation of

the net benefits of investment in infection control was beyond the scope of this work. However, as indicated in Chapter 10, the results of this study can be incorporated into economic models, together with data on the cost of infection control practices, to derive estimates of the net benefits of investing in infection control given various levels of effectiveness. The information generated by these models can subsequently be used to assist decision making regarding the allocation of resources to interventions to prevent and control infection. Models can be developed for a range of different activities. For example, models can be developed that assess the net benefits of investing in a comprehensive infection control programme, employing an additional infection control nurse, or investing in a particular piece of equipment thought to reduce the risk of infection. These models may relate to the prevention of all types of HAI or specific types of a HAI in a selected patient group or a wider patient population.

The results of the analysis that examined independent risk factors for HAI also have important implications for policy and practice. The results indicated that the risk of acquiring an HAI varied with both intrinsic and extrinsic risk factors. For example, the results of the analysis that examined independent risk factors for UTIs indicated that there were a number of intrinsic risk factors including sex (women had a greater risk of acquiring a UTI than men) and increasing age (the risk increased with age). The analysis also identified an extrinsic risk factor: the presence of a urinary catheter prior to the onset of infection. The presence of a urinary catheter was found to increase the risk of acquiring a UTI by almost three fold. Whilst it is acknowledged that the analysis was limited to a few selected potential risk factors for which data were available, the results still have important implications for policy and practice.

Information on independent intrinsic and extrinsic risk factors provides important data about which patients might be at greater risk of acquiring an infection. This information can be used by nursing and medical staff when planning and implementing care. For example, as indicated above the presence of a urinary catheter was found to significantly increase the risk of acquiring a UTI, thus

reinforcing the findings of earlier studies.[1 134 137 138 143 144] In terms of their implications for policy and practice, the results point to the need to question the need for catheterisation in individual patients. The results of an audit of infection control policies and practices in 19 hospitals in England and Wales indicated that catheterisation rates in patients admitted to similar specialties at these 19 hospitals varied considerably.[1] For example, amongst gynaecology patients, the catheterisation rate varied from 21% to 72%. Whilst some of this variation in rates may reflect case mix differences, such differences are unlikely to account for all the variation observed. Thus since catheterisation is a significant risk factor, the decision about whether to catheterise a patient should be taken carefully. When in use, care should be taken to minimise the risk of infection through the use of an appropriate catheter and appropriate catheter care. Where this involves additional resources, models can be developed that can provide important data on the costs and benefits of investment in a particular strategy and the results used to inform decision-making. In Chapter 10 an illustrative model was presented which demonstrated that investment in silver-alloy coated catheters resulted in positive returns at relatively low levels of effectiveness. Finally the results can be used to stimulate further research into the prevention of infections. That is the identification of key risk factors may be used to focus research into areas that can reduce the risk of these key independent factors.

The results of this study therefore have a number of implications for policy and practice. The results highlight the magnitude of the problem of infection in terms of the number of patients affected and the costs that fall on the hospital sector; they represent the potential gross benefits of prevention and when used in conjunction with data on the cost of prevention strategies they can be used to estimate the potential net benefits of investment in infection control.

These findings are of relevance to policy makers and health care professionals working at different levels in the health service. By demonstrating the magnitude of the problem, the results may help to keep the problem of HAI on

the Department of Health's policy agenda and through various initiatives also on the agenda of hospital trusts and health care professionals. The results may be used to raise awareness of the problem and when used in conjunction with data on the cost of prevention strategies may be used to inform decisions about how much should be invested in infection prevention and control and the nature of the programmes themselves.

11.7 Areas for future research

Several areas for future research were identified which would enable a more comprehensive understanding of the burden imposed by HAIs occurring in surgical patients. The focus of this study was the incidence of HAIs occurring in adult non-day case patients admitted to five surgical specialties common to most hospitals, and the economic burden these infections placed on the hospital sector as a result of additional in-patient care. Further work is now needed to assess the incidence of HAIs presenting after discharge from hospital and the economic burden infections presenting during the in-patient period and/or post-discharge place on the primary and secondary health care sector following discharge from hospital.

Another area for future research concerns the estimation of the benefits of investment in infection control activities. The research reported in this thesis was limited to the assessment of the economic burden HAIs placed on the secondary health sector as a result of additional in-patient care. As such the results presented represent the gross benefits of prevention. Net benefits will be dependent on the cost of effective infection control activities. Assessment of the net benefits of investment in specific infection control activities was beyond the scope of this study. However, a framework for assessing the net benefits of investment in specific prevention activities was presented in Chapter 10. This modelling framework needs to be further developed to establish the benefits of investment in various infection control activities, the results of which may be used to inform decisions regarding the allocation of funding and the nature of infection prevention activities.

Other areas for future research include the assessment of the incidence and cost of infections involving specific pathogens or groups of pathogens and the incidence of HAIs occurring in omitted patient groups and the economic burden imposed. Omitted surgical groups include patients admitted to the renal, cardiac, plastics, paediatrics, neonates and burns specialties; and day cases. The burden imposed by HAIs occurring in some of these omitted groups is likely to be substantial.

11.8 Conclusion

The problem of HAI has attracted considerable research interest in recent years. The results of this study add to the current body of knowledge providing detailed data on the incidence of HAI occurring in adult patients admitted to five surgical specialties common to most hospitals, risk factors for these infections and the economic burden these infections place on the hospital sector as a result of additional in-patient care. Overall 7.5% (95% CI: 6.4%, 8.6%) of adult patients admitted to selected surgical specialties of a district general hospital acquired one or more HAIs that presented in hospital. Independent risk factors for these infections were found to vary with site of infection. These infections were found to increase resource use. On average infected patients had a LOS 2.1 (95% CI: 1.8, 2.5) times that of uninfected patients and utilised resources valued at 2.3 (95% CI: 2.6, 3.0) times those used by uninfected patients. HAIs were estimated to prolong the hospital stay by 7.8 days (95% CI: 5.7, 10.0) and increase hospital costs by £2,254 (95% CI: £1,738, £2,770) per case. Whilst the results of this study reflect the experience of patients admitted to just one hospital site, for reasons discussed in section 11.3.5 it is likely that the results are generalisable to other heath care settings in the UK.

The results of the analysis that estimated the burden of HAIs occurring in patients admitted to the specialties covered in this study at other NHS hospital in England, provide important data on the magnitude of the problem at the National level. An estimated 154,920 (95% CI: 134,024 to 177,943) adult non-day case patients admitted to the specialties covered in this study at other NHS hospitals in England acquired one or more HAIs in 1994/5, utilising 1,153,726

(95% CI: 819,019 to 1,488,434) additional bed days and, as a result of additional in-patient care, cost the health sector an additional £327.77 million (95%CI: £240.58 to £414.98) with further costs borne by the primary health care sector, patients and carers.

The results of this study have important implications for policy and practice. The estimates demonstrate both the substantial burden these infections place on limited heath sector resources and at the same time the gross benefits of prevention. It is acknowledged that not all HAI can be prevented. However a proportion can. The results of a recent NAO survey of ICTs suggested that a 15% reduction in rates could be archived through improvements in infection control. If this were achieved then at the National level resources valued at an estimated £49.17 million (95% CI: £36.09 to £62.25 million) and 173,059 bed days (95% CI: 122,853 to 223,265) may be released for alternative use. These estimates represent the potential gross benefits of prevention. The net benefits will depend on the cost and effectiveness of infection control activities. Estimation of these net benefits was beyond the scope of this study. However a framework for assessing net benefits was presented and it is concluded that after taking into account the costs of prevention activities it is likely that in many cases a considerable level of resources would be released for alternative use.

The results of this study thus demonstrate that a substantial number of surgical patients acquire an infection in hospital and that these infections place a considerable burden on limited heath sector resources. The findings are of relevance to health care professionals and policy makers. They serve to raise awareness of the magnitude of the problem of HAI, and the potential benefits of prevention, and when used in conjunction with data on the costs of prevention strategies may be used to inform decisions about how much should be invested in infection prevention and control and the shape of infection control programmes. If improvements in infection control, and a reduction in rates follow, this is likely to result in the release of considerable resources for alternative use and most importantly improved patient outcomes.

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Research assistant training and seminar programme

A1.1 Introduction

This appendix contains details of the research assistants' training and seminar programme.

A1.2 Training programme

A1.2.1 Aim

To enable the research assistants to fulfill their role in the study by providing them with the necessary information and enabling them to develop the appropriate skills

A1. 2.2 Learning outcomes

At the end of the induction programme the research assistant will;

1. Understand the epidemiology of HAIs, how the cost of HAI has been studied in the past and some principles of infection control including the surveillance of HAI.

2. Understand the study methods and how the data collection will be organised.

3. Be able to discuss the project with patients and ask for their consent to be included in the study.

4. Be able to collect relevant information from clinical records and complete the data collection forms.

5. Be able to use the surveillance methods to identify patients with an infection.

6. Know how to enter data onto the database and validate some of the information.

7. Know who they should contact, and how to contact them if they encounter difficulties or need advice.

8. Understand the principles of the Data Protection Act and the standards of record keeping expected of them.

9. Understand their terms and conditions of service.

10. Be familiar with the areas they will be working in, and emergency procedures.

A.1.2.3 Areas covered:

Over the course of three weeks the following areas were covered:

1. Personnel issues: terms of service, disciplinary procedures.

2. The study site: the layout of the study hospital; hospital policies; library services.

3. Emergency procedures: fire; cardiac arrest and security procedures.

4. Aims and objectives of the study and envisaged benefits.

5. Study methods: recruitment, informed consent, patient confidentiality, the Data Protection Act and Standards for record keeping, surveillance methods, other data collection procedures (in-patient and post discharge phase), data coding, data entry, filing systems.

6. Basic health economics: costs arising from HAIs; valuing the cost of resources used; methods used to attribute resource use to the presence of an HAI.

7. Organisational issues: wards responsible for; introduction to ward areas; organisation of workload; time management; who to contact if there is a problem; where to find information of relevance to study; how to order stationary and other supplies.

8. Importance of accurate data collection.

9. Adapting to a new role and ethical issues
    - What to do if asked to help out on a ward.
    - What to do if you see something being done that you believe to be wrong or unethical.
    - What to do if a patient tells you something in confidence that you believe a member of the medical/nursing staff should be aware of.
    - What to do if a patient does not want to take part in the study – how to make them feel comfortable with their decision not to participate.

10. Importance of the Research Assistant's role in the study,

The programme commenced on the 14th March 1994 and was delivered over a three-week period. Much of the training was delivered by the project co-ordinator, with specialist sessions given by experts in the relevant field. For example, Helen Glenister (member of the steering Group) ran a one day workshop on surveillance of HAI. The Senior Infection Control Nurse from the

study site discussed infection control issues and the organistation of infection control services within the Trust. Nick Graves (research economist) gave a couple of sessions on the economics of HAI. Jennie Wilson (Member of the steering Committee) assisted in a couple, of sessions that considered the research assistant's new role and ethical issues that might arise over the course of the study. A Mental Health Services Manager ran a session on communication skills, and obtaining informed consent. The Trust's Community Liaison Nurse Manager ran a session which discussed the organisation of district nursing services in the area. Lynda Taylor (Steering Committee Member) provided an overview of the Public Health Laboratory Services. Over the course of the three week programme the research assistants visited the wards they would be working on, met with ward staff and familiarised themselves with the ward setting. The research assistants also visited a local GP practice. Finally the research assistants went on a weekend team building training programme. The latter was an outward-bound training programme that encouraged team building skills.

The programme was accompanied by a reader, which contained copies of key papers and a list of additional recommended references and journals. Papers addressing the following topics were included: incidence and prevalence of HAI; surveillance; risk factors for HAI; infection control; and the economic burden of HAI.

A1.2 Seminar Programme

The seminar programme covered the following areas: epidemiology of HAI, surveillance and infection control; financing and health care; research methodology; research and health policy; and health care evaluation. The programme was as follows.

Hospital Acquired Infection - Epidemiology, Surveillance and Infection Control

14.6.94	The epidemiology of hospital acquired infection and surveillance methods	Jennie Wilson
28.6.94	Infection Control	Lynda Taylor
12.7.94	Hospital Acquired Infection - the pathogens involved	Dr Dianna Barry
26.7.94	MRSA	Dr Barry Cookson
9.8.94	The role of the Consultant in Communicable Disease Control	Dr Rachael Joce

Financing and Managing Health Care

23.8.94	Financing health care - the alternatives	Ros Plowman
6.9.94	The NHS and the NHS reforms	Dr Jenny Roberts
20.9.94	Contracting in the NHS	Jane Bandcroft
4.10.94	Recent Reforms and Primary Care - The District Nurses Perspective	District nurse
18.10.94	The project - NHS applications	Nick Graves

Research Methodology

1.11.94	Research methods	Dr Mike Rowland
15.11.94	Costing Methodology	Nick Graves
29.11.94	Statistics made easy - part 1	Mark Griffin
13.12.94	Statistics made easy - part 2	Mark Griffin

Research and Health Policy

28.2.94	Does research affect policy? If so how?	Dr A Zwi
31.1.95	Research, Policy and the DOH perspective	Dr E Meerabeau

Economics and Health Care, Health Care Evaluation

14.2.95	Supply, demand and the market	Nick Graves
28.2.95	Health care evaluation	Nick Graves

Standards for Records and Record Keeping - Socio-economic Burden of Hospital Acquired Infection

1. Introduction

1.1 This paper sets out the standards to be applied to ensure confidentiality of patient centred data for the Socio-economic Burden of Hospital Acquired Infection study.

1.2 Nurses have a responsibility to adhere to the United Kingdom Central Council for Nursing, Midwifery and Health Visiting `Code of Professional Conduct for the Nurse, Midwife and Health Visitor' Standards for records and Record Keeping and abide by the following principles:

"As a registered nurse, midwife or health visitor you are personally accountable for your practice and, in the exercise of your professional accountability, must:

1. act always in a manner as to promote and safeguard the interests and well-being of patients and clients;

2. ensure that no action or omission on your part, or within your sphere of responsibility, is detrimental to the interests, condition or safety of patients and clients"

2. Maintaining Patient Confidentiality

2.1 Each patient that participates in this study will be identified by a unique study number. This number will be the only form of patient identification included in the computer held database.

2.2 Access to these patient data record files will be restricted to individuals named in Appendix A.

2.3. Personal details such as a patient's name, address, telephone number and hospital number will be stored in a separate file held on computer and on paper stored in a locked filing cabinet, within a locked room at the *study hospital*, or at the LSHTM or CPHL. CPHL has a secure perimeter fence and 24 hour security. The LSHTM has 24-hour security. Access to this file will be restricted to the individuals listed in Appendix B.

2.4 It will not be possible to access records held on computer without the use of a password. (Separate passwords will be required to gain access to the patients data record files and the patient personal detail files). Passwords will be changed periodically.

2.5 The project computers will be held in a locked room. Only individuals listed in Appendix A will be allowed access to the project computer.

2.6 Data exported for analysis will be entered onto designated computers at (LSHTM). Colindale has a secure perimeter fence and 24 hour security. The LSHTM has 24 hour security.

2.7 Access to the computers held at Colindale and the LSHTM will be restricted to individuals listed in appendix A.

2.8 Access to data held on these computers will be through the use of a password which will be changed periodically.

2.9 After completion of the research or its formal abandonment the key to the identities of all persons involved in the research and all personal data no longer required will be destroyed unless the Secretary of State directs otherwise in writing. The certificate of the Secretary of State to this effect shall be conclusive.

3. Patients Access to Records

3.1 In accordance with the Data Protection Act 1984 and the Access to Health Records Act 1990, participants in the study have the right to see their records. Information will only be withheld if in the view of the patients medical practitioner its release might cause serious harm to the physical or mental health of the patient or it would identify a third party.

3.2 If a patient requests access to their records, the request must be passed to the project co-ordinator, who will facilitate access.

3.3 When necessary advice regarding release of data will be sought from members of the Project Group.

4. Training of Research Assistants

4.1 The research assistants will receive training on the Data Protection Act and their professional responsibility for record keeping during their induction programme.

4.2 The project co-ordinator will provide additional training if the standards of record keeping described in this document are not being maintained.

4.3 Each research assistant will receive a copy of this document which they should read and sign.

Signature.....

Date.....

Appendix A

Individuals permitted to have access to patient records held on paper and on computer, the room where the study computer is held, the study computer and the computers to be used for analysis.

Project co-ordinator

Project economist

Project statistician

Research assistants

Project secretaries

Data entry clerk

Programme leader in surveillance and infection control

Statisticians from Steering Committee

Health economist from Steering Committee

Appendix B

Individuals allowed access to the patient personal details file

Project co-ordinator

Project economist

Project statistician

Research assistants

Project secretaries

Data entry clerk

Presentations concerning the Socio-economic Burden of Hospital Acquired Infection Study

Date	Presentation
Sept 1993 – April 1994	A number of seminars were held for clinical staff at the study hospital and also for district nurses within the community. The seminars provided an opportunity to discuss the aims and objectives of the socio-economic burden of HAI study and the methods we wished to employ, and provided staff at the study site with an opportunity to ask questions about the study.
Nov. 1994	Council of Europe, Strasbourg *'Economic and social aspects of hospital acquired infection.'*
March 1995	Canadian Nosocomial Infection Surveillance Programme - Semi-annual Meeting, Ottawa, Canada *'Estimating the costs of hospital acquired infection.'*
June 1995	University of Hertfordshire Research Leaders Forum 'The *socio-economic burden of hospital acquired infection.'*
Sept. 1995	Public Health Laboratory Service 20th Annual Scientific Conference *'Socio-economic burden of hospital acquired infection - An extensive follow up survey.'*
March 1996	European Infection Control Seminar, London. *'Hospital acquired infection – how much does it cost?'*
March 1996	The London Hospital Medical College, London. *'The economics of infection.'*
June 1996	University of Hertfordshire. *'The socio-economic burden of hospital acquired infection'*
July 1997	Diploma in infection control nursing – London. *'The cost of hospital acquired infection'*
Sept 1997	Infection control nurses association annual conference Swansea. *'Hospital-acquired infection – How much does it cost and why do we need to know?'*

Date	Presentation
June 1998	Infection Control Nurses Association, Wessex Regional Group Seminar. *'An expensive business – The real cost of hospital-acquired infection'.*
July 1998	The NHS Confederation 50th Anniversary Conference: The NHS: All our tomorrows. The Public Health Laboratory Service and hospital-acquired infection. *'The Economic challenge of hospital-acquired infection.'*
Nov. 1999	Nosocomial Infection National Surveillance Scheme, Surgical Site Infection Annual Meeting. *'The cost of surgical site infections'*
April 2000	Kelsey Lecture 2000, Central Sterilising Club. *'Hospital –acquired infection – Where is the Czar?'*
June 2000	Infection Control Nurses Association – London Branch. *`The socio-economic burden of hospital acquired infection'.*
June 2000	North Thames (East) Microbiology Consultants Meeting. *'The price of not washing your hand'*
July 2000	The first conference of the Economics of Infectious Disease. London School of Hygiene and Tropical Medicine. *'The burden of* hospital acquired infection'
Nov. 2000	The Infection Control Nurses Association International Conference. Edinburgh *'The economic burden of hospital acquired infection'*
March 2001	Risk and Responsibilities. A conference on hospital acquired infection. North Staffordshire Hospital NHS Trust. *'The socio-economic burden of hospital acquired infection'*
March 2001	International Conference on The Economics of Infectious Disease, London School of Hygiene and Tropical Medicine. *'Cost information informing policy and practice – A case study of hospital acquired infection'*
June 2001	Infectious Diseases and Hospital Acquired Infection Guidelines – The implementation challenge. A conference organised by the Health Studies Department at Oxford Brooks University, and held in London. *'Socio-economic benefits of better control of hospital acquired infection'.*

Wards involved in the Socio-economic burden of Hospital Acquired Infection Study

A4.1 Introduction

The Socio-economic Burden of Hospital Acquired Infection study involved the assessment of the incidence and economic burden of hospital acquired infections (HAIs) occurring in patients admitted to eight clinical specialties, common to most general hospital. Six research assistants were responsible for recruiting patients admitted to these specialties and subsequent data collection. For practical reasons it was not possible to recruit all patients admitted under the eight clinical specialties. As such, 14 study wards were selected. Each research assistant was responsible for the recruitment of patients admitted to the selected study wards. This appendix provides details of the number of wards included, their primary clinical specialty and the number and type of wards each research assistant was responsible for.

A4.2 Wards involved in the socio-economic burden of hospital acquired infection study.

Table A4.1 provides details of the wards involved, their clinical specialty and the number of beds on each ward. It should be noted that whilst each ward had a primary clinical interest, in practice patients admitted under other specialties were admitted to these study wards. Consequently, in addition to recording the ward, the research assistants recorded the clinical specialty and the consultant patients were admitted under.

Table A4.1 Number of wards involved in the Socio-economic Burden of HAI study

Clinical specialty	Number of wards	Total number of beds
General medicine	3*	75
General surgery	2	60
Orthopaedics	2	60
Urology	1	15
Gynaecology	1	20
Elderly care	2	56
ENT	1	15
Obstetrics**	2	50

one ward included a 5 bed coronary care unit
*Only those patients who had a caesarean section were eligible for recruitment.

A4.3 Number of wards each research assistant was primarily responsible for

Table A4.2 provides details of the number of wards each research assistant was primarily responsible for. The allocation of wards took into account both the number of beds available on each ward and the types of patients admitted to each of the selected wards, and the implications this might have for recruitment and subsequent data collection.

Table A4.2 The allocation of wards to research assistant

Research assistant	Wards allocated	Total number of beds
1	2 care of the elderly wards	60
	Obstetrics*	50*
2	I surgical ward	30
	I medical ward	15
3	I gynaecology ward	20
	1 surgical ward	30
4	1 urology ward	15
	1 medical ward	30
5	2 orthopaedic wards	60
	1 ENT ward	15
6	I medical ward	30

*Only those patients who had a caesarean section were eligible for recruitment.

Patient information sheet, consent forms and decline to participate form

A5.1 Introduction

This appendix contains a copy of the following documents:

a) The patient study information form.
b) The consent form administered to patients who agreed to participate in the study.
c) The consent form administered to relatives of patients who were unable to give their own consent to participation in the study.

INFORMATION SHEET

COSTING INFECTIONS

A small number of patients develop an infection following hospital treatment; this can occur whilst in or shortly after leaving hospital. The *study* hospital is involved in a study, funded by the Department of Health, looking at how many patients develop such infections and the cost of these to the health service and the patients concerned. We would be grateful if you would take part in this study.

We would like to gather information about your condition and the treatment you receive. This will involve looking at your medical and nursing records. After you have left hospital we may need to contact your GP.

You may also be contacted about a month after you have left hospital to find out how you are feeling and how you have been since leaving hospital. Any information you give us will be kept **strictly confidential.**

Since the information we obtain from you will be treated in total confidence, and will not be reported to your doctor or nurse, it is important that you also mention any concerns you might have about your health and treatment to them.

We would appreciate your help with this study. If you are willing, would you please sign the attached consent form. If you do not wish to participate, it will not affect the treatment you are given in any way.

If you have any questions or require any further information about the study please do not hesitate to ask *(insert name)*_____ your research nurse or contact Rosalind Plowman the Project Co-ordinator. *(Insert name of research nurse)*_____ will visit the ward daily but can also be contacted on Ext. XXX at the *study hospital.* Rosalind Plowman can be contacted either on Ext. XXX at the *study* hospital or at the Central Public Health Laboratory, London, Tel 081 200 4400 ext. 4234.

Thank you for your help.

Central Public Health Laboratory, 61 Colindale Avenue, London NW9 5HT

COSTING INFECTIONS

CONSENT FORM

I _____

of _____

_____

agree to take part in this study looking at the extent of and cost of hospital infections. I have read the study information sheet and understand that I have given my consent to the collection of data on my condition and the treatment I receive. Whilst in hospital this information will be obtained from my medical and nursing notes. After leaving hospital my GP may be contacted to obtain this information.

I also understand that taking part in this study may involve my completing a questionnaire one month after leaving hospital.

I understand that any information obtained from my medical and nursing notes and any information given will be kept strictly confidential.

_____ _____

Patient's signature Date

_____ _____

Research Assistant's signature Date

Central Public Health Laboratory, 61 Colindale Avenue, London NW9 5DF

COSTING INFECTION

CONSENT FORM

I _____

of _____

_____

give consent that:

_____

of _____

_____

may take part in this study looking at the extent of and cost of hospital infections. I have read the study information sheet and understand that I have given consent to the collection of data on _____condition and the treatment he/she receives. Whilst in hospital this information will be obtained from my medical and nursing notes. After leaving hospital his/her GP may be contacted to obtain this information.

I also understand that taking part in this study may involve _____ completing a questionnaire one month after leaving hospital.

I understand that any information obtained from my medical and nursing notes and any information given will be kept strictly confidential.

_____ _____

Relative's signature Date

_____

Relationship to patient

_____ _____

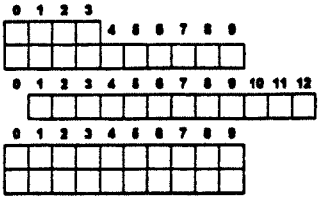
Research Assistant's signature Date

Central Public Health Laboratory, 61 Colindale Avenue, London NW9 5DF

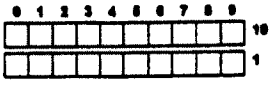
PATIENT DECLINES TO PARTICIPATE IN THE STUDY OR IS EXCLUDED FROM STUDY

Q1 Study Number

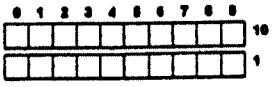
Q2 Date of admission:



Q3 Day of attempted recruitment:



Q4 RA Code:



Q5

- ☐ Pt declines participation
- ☐ Unable to recruit pt due to lack of time
- ☐ Unable to find a suitable time to recruit pt
- ☐ Pt too sick/next of kin unavailable/inappropriate to ask next of kin
- ☐ Pt admitted on a non-recruiting day
- ☐ Weekend admission

Q6 Age group:

- 18-30 ☐
- 31-40 ☐
- 41-50 ☐
- 51-60 ☐
- 61-80 ☐
- 81-100 ☐
- over 100 ☐

Q7 Specialty:

- Surgery ☐
- Medicine ☐
- Care of the elderly ☐
- Orthopaedics ☐
- Urology ☐
- Obs & Gynae ☐
- ENT ☐

Q8 Sex:

- Male ☐
- Female ☐

Q9 Type of admission:

- Elective ☐
- Emergency ☐

Definitions of infections presenting during the patient's hospital stay

A6.1 Introduction

The definitions of hospital acquired infections used in this study, with the exception of the definition of a chest infection, are those developed and used in the recent study, `A Study of Surveillance Methods for Detecting Hospital Infections.'[77]

A6.2 Hospital acquired infection (HAI)

An infection found to be active (or under active treatment at the time of survey) which was not present or incubating on admission to hospital.[6] Where doubt exists, infections appearing at 72 hours or more after admission should be classified as hospital acquired.[248 249] A patient readmitted with established infection resulting from an earlier admission is recorded as having a HAI.[23] Transfers admitted from another hospital with a nosocomial infection acquired there will be coded separately.

A6.3 Community Acquired Infection (CAI)

An infection found to be active (or under active treatment) at the time of survey, which was present or incubating on admission to hospital.[250]

A6.4 Criteria for Diagnosing the Presence of Infection

There must be clinical evidence of infection except in the case of central nervous system infections where laboratory evidence may suffice. Colonisation should be excluded.

A6.4.1 Clinical evidence.

This includes the cardinal signs and symptoms as defined in this document which are presented, or have been present during the patient's stay in hospital. Some signs and symptoms may include fever $\geq$37.8°C.[251] where infection is the only known cause, inflammation (i.e. redness, swelling, pain, heat) and the production of pus.

A6.4.2 Laboratory evidence

This is present if the results of specimens meet the criteria defined in this document. With some infections, a clinician's diagnosis of infection based on clinical signs and symptoms with or without laboratory evidence will be accepted.

A6.5 Date of onset

This is the date the first clinical evidence of infection appeared, or if no signs and symptoms are present, the date the specimen used to make or confirm the diagnosis was collected, whichever comes first.

A6.6 Urinary tract infection

A5.6.1 Patients without a urinary catheter in situ

A urinary tract infection is present if the patient has two or more of the following signs and symptoms:

- Fever $\geq 37.8^0C$ with no other recognised cause
- Urgency
- Frequency
- Dysuria

WITH OR WITHOUT

- A positive urine culture, that has $\geq 10^5$ colonies per ml of urine with no more than two species of micro-organisms.
- A positive urine culture that has $<10^5$ colonies per ml of urine of a single micro-organism in the presence of an antibiotic being given to treat an urinary tract infection.

OR

- A positive urine culture with more than 2 species of micro-organisms identified and the presence of 10 white blood cells or more seen on high power film.

Note:

- If the patient is unable to communicate the above signs and symptoms a clinician's diagnosis of urinary tract infection will suffice.
- Surveyor should note whether clinical, or clinical with laboratory evidence is used to determine the presence of infection.
- Infections of organs of the urinary tract (kidney, ureter, bladder or urethra) following surgery to that area should be recorded as surgical wound infection.

A6.6.2 *Patients with a catheter in situ*

A clinician's diagnosis of a urinary tract infection will suffice.

WITH OR WITHOUT

- A positive urine culture, that has $\geq 10^5$ colonies per ml of urine width no more than two species of micro-organisms.
- A positive urine culture that has $<10^5$ colonies per ml of urine of a single micro-organism in the presence of an antibiotic being given to treat an urinary tract infection.

OR

- a positive urine culture with more than 2 species of micro-organisms identified and the presence of 10 white blood cells or more seen on high power film.

Note:

- The surveyor should note whether clinical, or clinical with laboratory, evidence is used to determine the presence of infection.
- Infection of the urethra occurring at the insertion site of a catheter should be included as an urinary tract infection. The presence of the device (i.e. catheter) should be noted.
- Infections of organs of the urinary tract (kidney, ureter, bladder or urethra) following surgery to that area should be recorded as surgical wound infection.

A6.7 Asymptomatic bacteriuria

A6.7.1 Asymptomatic bacteriuria

This is present if:

- There are two positive urine cultures that have $\geq 10^5$ colonies per ml of urine with repeated isolation of the same micro-organism and no more than two species of micro-organisms.
- The patient does not have any of the following signs and symptoms: fever ($<37.8^0$C); urgency; frequency; dysuria.

A6.8 Infections of upper respiratory tract and ear

A clinician's diagnosis of one or more of the following with or without microbiological evidence of infection:

- Furuncle
- Rhinitis (infective)
- Sinusitis
- Pharyngitis
- Epiglottis
- Tonsillitis
- Otitis media

Note:

- Infection of the anterior nares surrounding the insertion site of a nasogastric tube should be included as upper respiratory tract infection. The presence of the nasogastric tube should be noted.
- Infections of the upper respiratory tract (ear, nose or throat) following surgery to that area should be recorded as surgical wound infection.

A6.9 Pneumonia

Pneumonia is present if the patient has appropriate chest signs including consolidation and/or x-ray changes showing new or progressive infiltrate and one or more of the following:

- New or increased production of sputum
- Fever ($\geq 37.8^0$C)

If the above are not present, a clinician's diagnosis of pneumonia will suffice.

A6.10 Chest Infection

A chest infection is present if the clinician has diagnosed a chest infection and the patients' symptoms do not meet the definition of pneumonia

A6.11 Other lower respiratory tract infection

A clinician's diagnosis of one or more of the following will suffice:

- Empyema
- Lung abscess
- Tracheitis
- Bronchitis
- Mediastinitis

Note:

- Infections of any one area of the lower respiratory tract (trachea, bronchus, lung, mediastinum) following surgery to that area should be recorded as a surgical wound infection.

A6.12 Wound infection

A wound is defined as a break in the epithelial surface (skin or mucous membrane) and the underlying tissue made by some positive act such as an accident or surgical incision. Burns should be excluded. An ulcer or pressure sore is not a wound for the purposes of this definition.

All wound infections must have one of the following:

- Purulent discharge in the wound
- Purulent discharge exuding from a wound
- Purulent discharge seen on direct examination at the operative site.

A6.12.1 Major infection

This is present when the wound is broken down, gaping or completely dehisced or there is evidence of septicaemia, spreading cellulitis and lymphangitis.

A6.12.2 Minor infection

This is present when the wound is not broken down, gaping or completely dehisced and there is no evidence of septicaemia, spreading cellulitis and lymphangitis.

A6.12.3 Surgical wound infection

This is present if infection occurs at the incision site or operative site (including drains) within 30 days after surgical operation if no implant is left in place, or within one year if an implant is in place. The infection must appear to be related to the surgical procedure.

A6.12.4 Accidental wound

This is present if infection occurs at or in the accidental wound site.

Note:

- Infections occurring at the entry site of a device which has required an incision for insertion should be noted as surgical wound infection (e.g. tracheostomy, intravascular catheters, renal dialysis catheters, suprapubic catheter). The presence of the device should be noted.

A6.13 Skin infection

A skin infection is present if there is inflammation of the skin and infection is the only known cause. There may or may not be pus on the skin.

Note:

- Ulcers, pressure sores and otitis externa should be excluded.

A6.14 Burn infection

A burn infection is present if one or both of the following are present:

- Discharge of purulent material
- Graft rejection with clinical (i.e. inflammation and/or pus) evidence of infection.

A6.15 Septicaemia

Septicaemia is present if the patient has at least one of the following signs or symptoms:

- Fever ($\geq 37.8^{0}C$) with no other recognised cause
- Chills or rigors
- Hypotension

AND

- Micro-organisms are isolated from one or more blood cultures taken when the symptoms were present.

A6.16 Bacteraemia

Bacteraemia is present if:

- Micro-organisms have been isolated from one or more blood cultures taken on the one occasion, except in the isolation of a skin contaminant (e.g. diptheroids, coagulase negative staphylococci), when two or more positive blood cultures drawn on separate occasions should be obtained.

AND

- The patient does not have any clinical signs or symptoms of infection, i.e. there is no fever (<37.8^{0}C), chills or hypotension.

A6.17 Eye infection

An eye infection is present if there is new purulent discharge or pus within or on the surface of the eye.

Note:

- Infections of the skin surrounding the eye, e.g. stye, should be noted as skin infections.
- Infection of the eye following surgery should be noted as a surgical wound infection.

A6.18 Central nervous system infection

A central nervous system infection must meet at least one of the following criteria:

- Micro-organisms in cerebral-spinal fluid (CSF), but excluding contaminants, with or without white blood cells.

- White blood cells in CSF in the absence of micro-organisms if the patient is receiving antibiotics.

- White blood cells in the CSF in the absence of micro-organisms if there is no other obvious cause for their presence.

A6.19 Genital tract infection

Genital tract infections can be divided into post-partum and other genital tract infections.

A6.19.1 Post-partum infection

This requires systemic evidence of infection with a new purulent discharge.

A6.19.2 Other genital infection

This is present if there is new purulent discharge with or without microbiological evidence of infection.

Note:

- Episiotomy should be classified as a surgical wound and a perineal tear classified as an accidental wound.
- Infection of any one area of the genital tract following surgery to that area should be recorded as wound infection.

A6.20 Gastrointestinal infection

A gastrointestinal infection is present if diarrhoea and/or vomiting occurs which is not as a result of any of the following:

- Diagnostic tests
- Therapeutic regimens
- Other underlying non-infectious causes

Note:

- The presence of a gastrointestinal infection should be supported whenever possible by microbiological evidence.

A6.21 Other abdominal infection

Other abdominal infections include a clinician's diagnosis, with or without microbiological evidence, of the following:

- Intra-abdominal abscess formation
- Peritonitis

Note:

- Appendicitis, cholecystitis, pancreatitis and diverticulitis should not be recorded as infections unless the presence of pus is noted.
- Infections within the abdomen following surgery to the affected area should be recorded as surgical wound infection.

A6.22 Bone and joint infections

These require a clinician's diagnosis of septic arthritis or osteomyelitis, with or without microbiological evidence.

A6.23 Systemic infection

This requires a clinician's diagnosis, with or without laboratory evidence (including serology), of generalised bacterial, viral, fungal or parasitic infection without a definable single site of infection (e.g. measles, mumps, herpes, varicella).

A6.24 Other infections

These require a clinician's diagnosis, with or without microbiological evidence of infection, which does not fall into the above categories (e.g. varicose ulcers, rectal abscesses, pressure sores, otitis externa, oral thrush and non-therapeutic related hepatitis). This includes clinical symptoms of infectious hepatitis (A,B, Non A and Non B) and serum positive for hepatitis B antigen without symptoms.

Examples of data collection forms used

A7.1 Introduction

This appendix contains examples of some of the data collection forms used. The following forms are included:

i) General data collection form. Information relating to the type of admission, reason for admission, the patients' social circumstances, formal and informal care received prior to admission, ward transfers, discharge diagnosis and care organised on discharged were recorded on this form.

ii) Drug data collection forms. Information on drugs and infusions administered were recorded on a number of different data collection forms. The enclosed examples were used to record infusions and drugs administered by the intravenous, intra-muscular and/or subcutaneous route during the patients' hospital stay. Similar forms were available to record, tablets, topical drugs and other drugs administered.

iii) Investigations data collection form. Information on investigations undertaken (e.g. cardiac tests, endoscopies and x-rays) were recorded on this form, together with information on devices in place (e.g. intravenous lines, wound drains and urinary catheters); care provided by health care professionals allied to medicine (e.g. physiotherapists, occupational therapists and dieticians); and nursing care administered to patients during their hospital stay.

iv) Operation data collection form. Operation details, including the type of anaesthetic, procedures performed and duration of surgery were recorded on this form.

v) Laboratory tests data collection form. Information on laboratory tests performed were recorded on this form. Specimens taken either at the pre-assessment clinic or in the accident and emergency department were recorded in the appropriate columns. If the test was performed out of normal working hours the test was recorded in the 'o/c' (on call) column.

vi) Infections data collection form. Information on both hospital and community acquired infections were recorded on this form. Where possible, the date of onset, site of infection, devices in situ and pathogens involved were recorded.

With the exception of the general and the laboratory tests data collection forms, the forms contained within this appendix apply to the first two weeks in hospital. The laboratory tests data collection form only applies to the first week in hospital. Additional forms were available for patients who had a length of stay that exceeded these time-periods.

GENERAL

Q1 Study Number

Q2 RA _____

0 1 2 3 4 5 6 7 8 9 (10, 1)

Q3 Day recruited:
(99 = pre-admission clinic)
0 1 2 3 4 5 6 7 8 9 (10, 1)

Q4 Readmission - last admission within the last month?

☐ Yes ☐ No

Q5 If yes - is this admission linked to the last admission?

☐ Yes ☐ No

Q6 What is the link between the current and previous admission

Q7 Type of admission:

- ☐ elective via pre-admission clinic
- ☐ elective direct to ward
- ☐ urgent direct to ward
- ☐ emergency via A+E
- ☐ emergency via OPD
- ☐ emergency GP referal direct to ward
- ☐ transfer from another ward
- ☐ via day hospital
- ☐ transfer from another hospital
- Other 0 1 2 3 4 5 6 7 8 9 (1)

Q8 Previous study number
0 1 2 3 4 5 6 7 8 9 (1000, 100, 10, 1)

Q9 Date seen in pre-admission clinic if applicable.
0 1 2 3 4 5 6 7 8 9
0 1 2 3 4 5 6 7 8 9 10 11 12
0 1 2 3 4 5 6 7 8 9

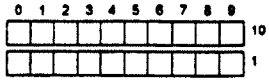
Q10 Date of admission:
0 1 2 3 4 5 6 7 8 9
0 1 2 3 4 5 6 7 8 9 10 11 12
0 1 2 3 4 5 6 7 8 9

Q11 Admission speciality:

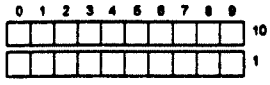
- ☐ General medicine
- ☐ General surgery
- ☐ Orthopaedics
- ☐ Urology
- ☐ Gynae
- ☐ c/o elderly
- ☐ ENT
- ☐ Obs

Q12 Ward admitted to: _____
0 1 2 3 4 5 6 7 8 9 (10, 1)

Q13 Admitting Consultant_____

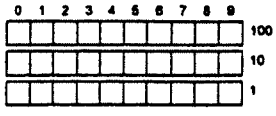


Q14 Joint care on admission - consultant

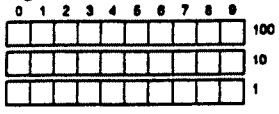


Q15 Sex ☐Male ☐Female

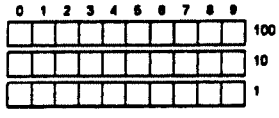
Q16 GP_____



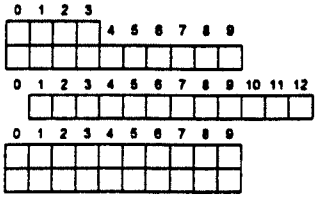
Q17 Age



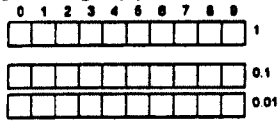
Q18 Weight (kgs)



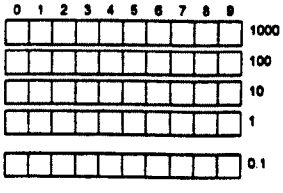
Q19 DOB



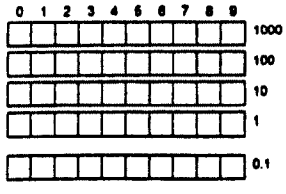
Q20 Height (ft)



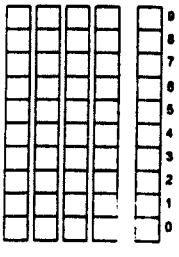
Q21 Reason for admission:



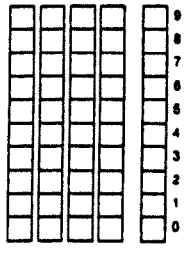
Q22 Diagnosis on admission:



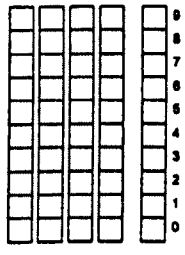
Q23 Co-morbidities 1



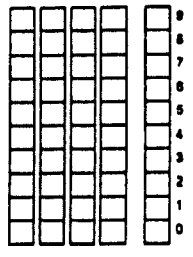
Q24 Co-morbidities 2



Q25 Co-morbidities 3



Q26 Co-morbidities 4



Q27 Marital status

- ☐ single
- ☐ married living with husband/wife/partner
- ☐ married not living withhusband/wife
- ☐ widowed
- ☐ divorced

Household Size

Q28 Number of adults in household including patient

0 1 2 3 4 5 6 7 8 9 ☐☐☐☐☐☐☐☐☐☐ 1 **>18 yrs**

Q29 Number of children in household

0 1 2 3 4 5 6 7 8 9 ☐☐☐☐☐☐☐☐☐☐ 1 **<18 yrs**

Q30 How many children have you got?

0 1 2 3 4 5 6 7 8 9 ☐☐☐☐☐☐☐☐☐☐ 1 **all ages**

Q31 How many children under 5 years old

0 1 2 3 4 5 6 7 8 9 ☐☐☐☐☐☐☐☐☐☐ 1

Q32 How many children under 16 years old

0 1 2 3 4 5 6 7 8 9 ☐☐☐☐☐☐☐☐☐☐ 1

Q33 How many children under 11 years old

0 1 2 3 4 5 6 7 8 9 ☐☐☐☐☐☐☐☐☐☐ 1

Q34 How many children under 18 years old

0 1 2 3 4 5 6 7 8 9 ☐☐☐☐☐☐☐☐☐☐ 1

Q35 Currently living in Residential home ☐ **Nursing home** ☐ **Sheltered accomodation** ☐

Hostel ☐ **Hospice** ☐ **Own Home** ☐ **Relatives Home** ☐

CHILD CARE

Q36 Have you had to arrange any addditional care for your children whilst in hospital?

Yes ☐ **No** ☐

900 is a half day

Q37 If yes from whom?

- ☐ Husband/wife/partner
- ☐ other relative (s)
- ☐ friend/neighbour (s)
- ☐ nanny/childminder

other: ☐

Q38 Husband/wife partner - days caring for chn

0 1 2 3 4 5 6 7 8 9 ☐☐☐☐☐☐☐☐☐☐ 100
☐☐☐☐☐☐☐☐☐☐ 10
☐☐☐☐☐☐☐☐☐☐ 1

Q39 Husband/wife partner - days off work

0 1 2 3 4 5 6 7 8 9 ☐☐☐☐☐☐☐☐☐☐ 100
☐☐☐☐☐☐☐☐☐☐ 10
☐☐☐☐☐☐☐☐☐☐ 1

Q40 Relative 1- days caring for chn

0 1 2 3 4 5 6 7 8 9 ☐☐☐☐☐☐☐☐☐☐ 100
☐☐☐☐☐☐☐☐☐☐ 10
☐☐☐☐☐☐☐☐☐☐ 1

Q41 Relative 1- days off work

0 1 2 3 4 5 6 7 8 9 ☐☐☐☐☐☐☐☐☐☐ 100
☐☐☐☐☐☐☐☐☐☐ 10
☐☐☐☐☐☐☐☐☐☐ 1

Q42 Occupation ☐

Q43 Relative 2- days caring for chn

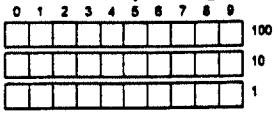
0 1 2 3 4 5 6 7 8 9 ☐☐☐☐☐☐☐☐☐☐ 100
☐☐☐☐☐☐☐☐☐☐ 10
☐☐☐☐☐☐☐☐☐☐ 1

Q44 Relative 2- days off work

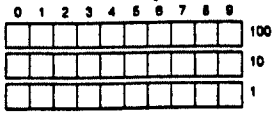
0 1 2 3 4 5 6 7 8 9 ☐☐☐☐☐☐☐☐☐☐ 100
☐☐☐☐☐☐☐☐☐☐ 10
☐☐☐☐☐☐☐☐☐☐ 1

Q45 Occupation ☐

Q46 Relative 3- days caring for chn



Q47 Relative 3- days off work

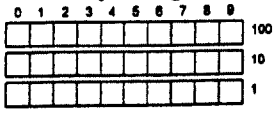


Q48 Occupation

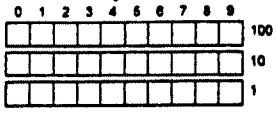
Freinds/Neighbours

900 is a half day

Q49 F/N 1- days caring for chn

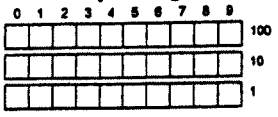


Q50 F/N 1- days off work

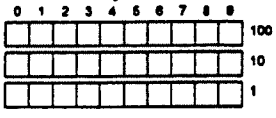


Q51 Occupation

Q52 F/N 2 - days caring for chn

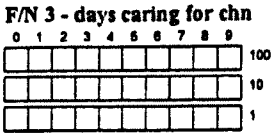


Q53 F/N 2- days off work

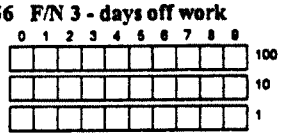


Q54 Occupation

Q55 F/N 3 - days caring for chn



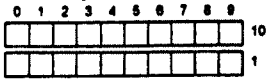
Q56 F/N 3 - days off work



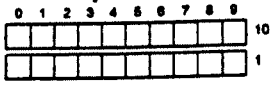
Q57 Occupation

Additional paid childcare

Q58 1/2 days



Q59 Full days



Other Dependents

Q60 Other dependents? (Elderly defined as over 70 years)

☐None ☐1 elderly R ☐2 elderly R ☐pets ☐husband/wife/partner ☐other relative (not elderly)

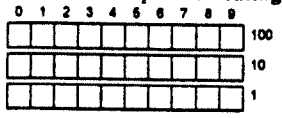
☐ elderly F/N ☐F/N (not elderly) other

Q61 Whilst in hospital have you had to arrange for any one to care for these dependents?

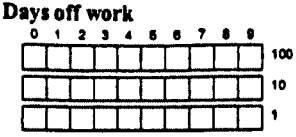
☐ No ☐Husband/wife/partner ☐other relative ☐friend/neighbour ☐respite care ☐atery etc Soc☐ervcs pets

RELATIVES

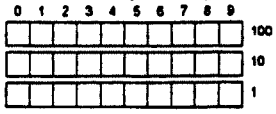
Q62 Husband/wife/partner caring for D



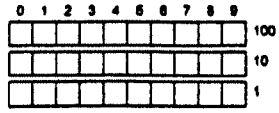
Q63 Days off work



Q64 Relative1- days caring for D

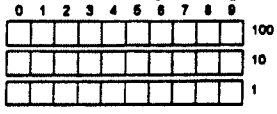


Q65 Relative 1- days off work

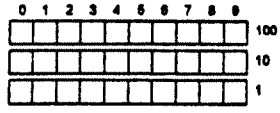


Q66 Occupation

Q67 Relative 2- days caring for D

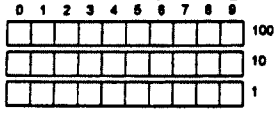


Q68 Relative 2 - days off work

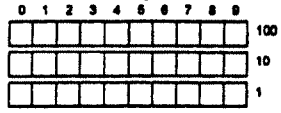


Q69 Occupation

Q70 Relative 3- days caring for D



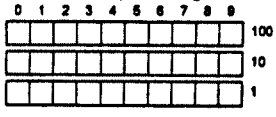
Q71 Relative 3 - days off work



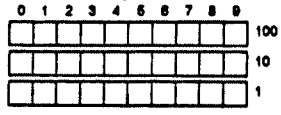
Q72 Occupation

FRIENDS/NEIGHBOURS

Q73 F/N 1 - days caring for D

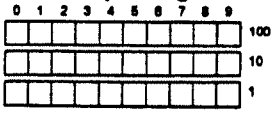


Q74 F/N 1 - days off work

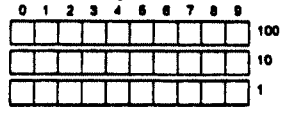


Q75 Occupation

Q76 F/N 2 days caring for D

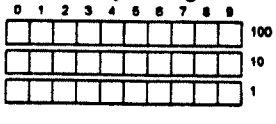


Q77 F/N 2- days off work

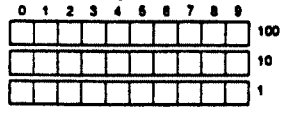


Q78 Occupation

Q79 F/N 3- days caring for D

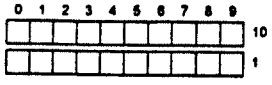


Q80 F/N 3- days off work



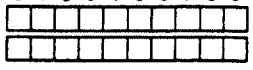
Q81 Occupation

Q82 OPH etc



Q83 Self financed
NHS
Local Auth (no contr,)
Local Auth (contr.)
Local Auth (not sure)

Q84 Cost per day in a cattery/kennels (£)



SERVICES RECEIVED PRE- ADMISSION

Q85 Community/social services received pre-admission:	Q86 Days/week	Q87 Weeks	Q88 Months
District Nurse			
Home help			
MOW			
Con. advisor			
Mac.Nurse			
CTT			
OT			
EST			
Day Hosp			
Other:			

Q89 Help received from family and friends pre-admission?

	Daughter son etc.	Partner	Friend neighbour	Other	Q90 Weeks	Q91 Months
Shopping						
Cleaning						
Washing/Dressing						
Cooking						
Daily check						
Twice weekly check						
Weekly check						

Q92 Live in carer - friend ☐ Live in carer - relative ☐

OCCUPATION/EMPLOYMENT

Q93 Employment status prior to admission to hospital.

- ☐ employed full time
- ☐ employed part time
- ☐ employed but temporary laid off
- ☐ unemployed looking for work
- ☐ unable to work because of illhealth (disabled)
- ☐ Housewife/ house husband
- ☐ student (FT)
- ☐ retired
- ☐ other - please specify

Present or most recent job?

_____

Q94 Job description

- ☐ **Self employed with employees**
- ☐ **Self employed without employees**
- ☐ **Employed - manager**
- ☐ **Emplyed - foreman/supervisor**
- ☐ **Employed - normal employee/apprentice**

Q95 Social Class

0 1 2 3 4 5 6 7 8 9 → 1

Q96 Socio economic group

0 1 2 3 4 5 6 7 8 9 → 10
0 1 2 3 4 5 6 7 8 9 → 1
0 1 2 3 4 5 6 7 8 9 → 0.1

Q97 Husband/wife/partners occupational status?

- ☐ N/A single/not living with partner/husband/wife
- ☐ employed full time
- ☐ employed part time
- ☐ employed but temporary laid off
- ☐ unemployed looking for work
- ☐ unable to work because of illhealth (disabled)
- ☐ Housewife/husband
- ☐ student (FT)
- ☐ retired
- ☐ other - please specify

Present or most recent job

_____

Q98 Job description

- ☐ **Self employed with employees**
- ☐ **Self employed without employees**
- ☐ **Employed - manager**
- ☐ **Emplyed - foreman/supervisor**
- ☐ **Employed - normal employee/apprentice**

Q99 Social Class

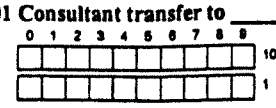
0 1 2 3 4 5 6 7 8 9 → 1

Q100 Socio economic group

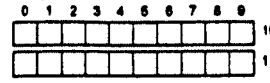
0 1 2 3 4 5 6 7 8 9 → 10
0 1 2 3 4 5 6 7 8 9 → 1
0 1 2 3 4 5 6 7 8 9 → 0.1

Consultant Transfer 1

Q101 Consultant transfer to _____

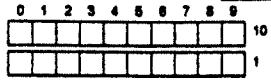


Q102 Day of transfer:

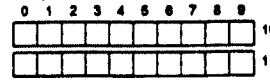


Consultant transfer 2

Q103 Consultant transfer to _____

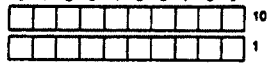


Q104 Day of transfer

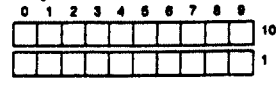


Consultant transfer 3

Q105 Consultant transfer to _____

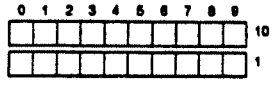


Q106 Day of transfer

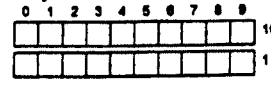


Ward transfer 1

Q107 Ward transfered to:

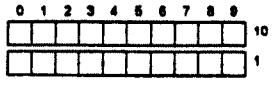


Q108 Day of transfer

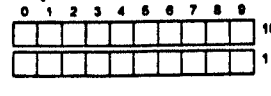


Ward transfer 2

Q109 Ward transfered to:

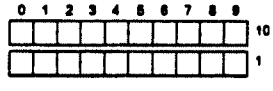


Q110 Day of transfer

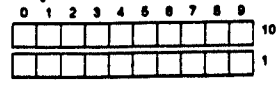


Ward transfer 3

Q111 Ward transfered to:

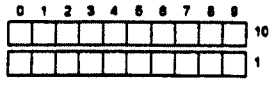


Q112 Day of transfer

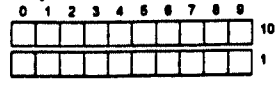


Ward transfer 4

Q113 Ward transfered to:



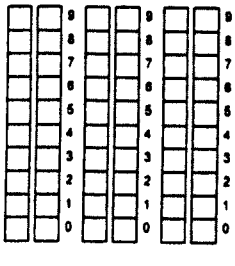
Q114 Day of transfer



Q115

Consultant Referral 1

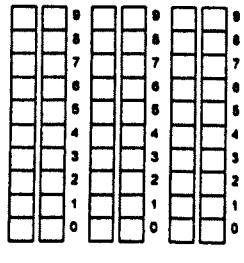
Code Day Nos of days



Q116

Consultant Referral 2

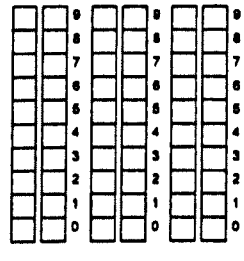
Code Day Nos of days



Q117

Consultant Referral 3

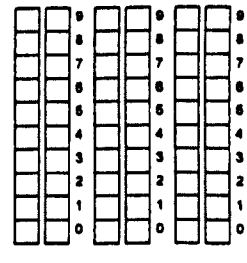
Code Day Nos of days



Q118

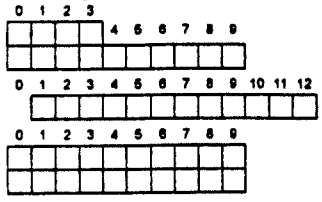
Consultant Referral 4

Code Day Nos of days



DISCHARGE

Q120 Discharge date:



Q119 Discharged to:

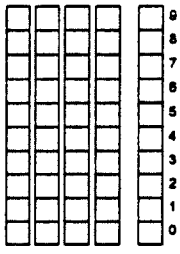
- ☐ Home
- ☐ Other ward <1week
- ☐ Other hosp <1week
- ☐ Hospice
- ☐ Nursing home
- ☐ Relatives
- ☐ RIP

- ☐ Other ward >1week
- ☐ Other hosp>1week
- ☐ Residential home
- ☐ Convalescent home
- ☐ Sheltered accom

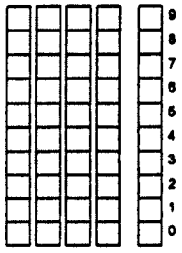
Other _____

Q121 ☐ Ambulance ☐ Hospital Car

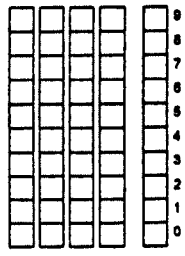
Q122 Diagnosis on discharge _____



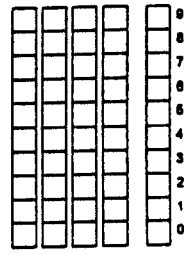
Q123 Diagnosis on discharge _____



Q124 Diagnosis on discharge _____

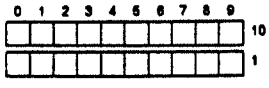


Q125 Diagnosis on discharge _____

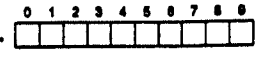


Q126 SERVICES ON DISCHARGE

R.O.S (days)

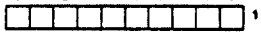


- ☐ Ward
- ☐ GP surgery
- ☐ OPD
- ☐ District Nurse
- ☐ A&E

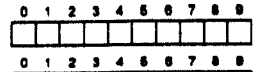
Other 

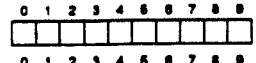
Q127

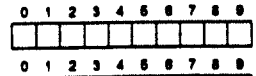
- ☐ District Nurse
- ☐ Macmillan Nurse
- ☐ Continence Advisor
- ☐ CTT
- ☐ EST
- ☐ MOW
- ☐ HH
- ☐ Social worker
- ☐ Physio
- ☐ OT
- ☐ CPN
- ☐ GP follow up

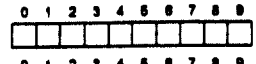
Other 

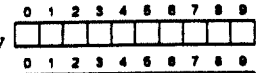
Q128

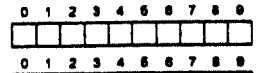
OPA  weeks

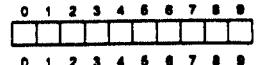
ECG  weeks

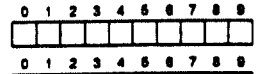
Endoscopy  weeks

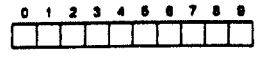
TWOC  weeks

Lithotripsy  weeks

Day Hosp  Days/week

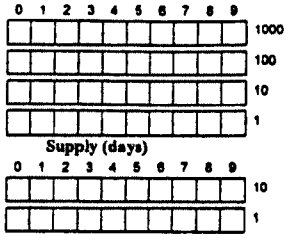
 Number of weeks

Other  code

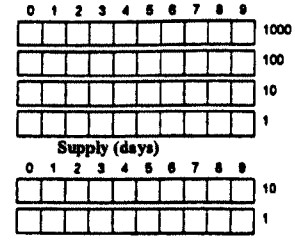
 weeks

DRUGS SUPPLIED

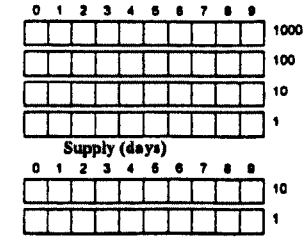
Q129 Drug 1



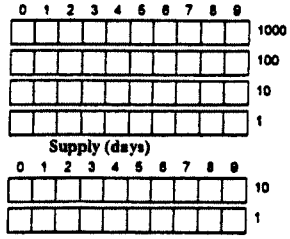
Q130 Drug 2



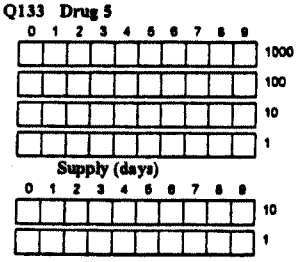
Q131 Drug 3



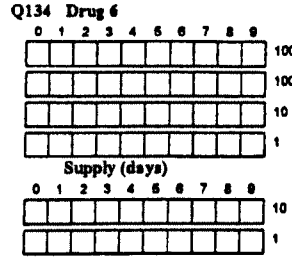
Q132 Drug 4



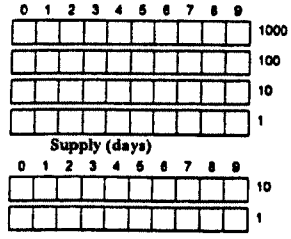
Q133 Drug 5



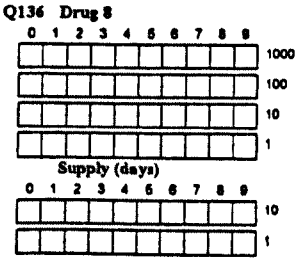
Q134 Drug 6



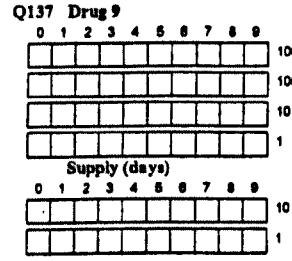
Q135 Drug 7



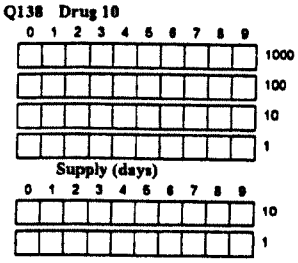
Q136 Drug 8



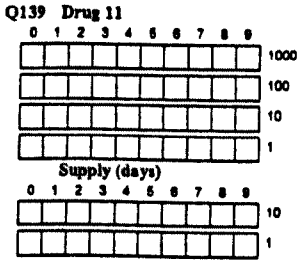
Q137 Drug 9



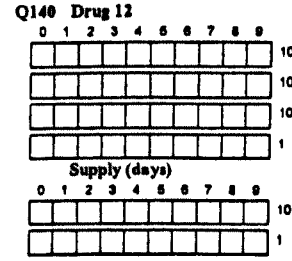
Q138 Drug 10



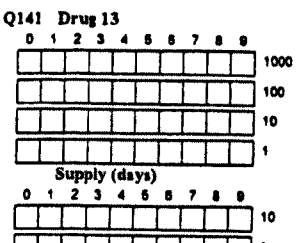
Q139 Drug 11



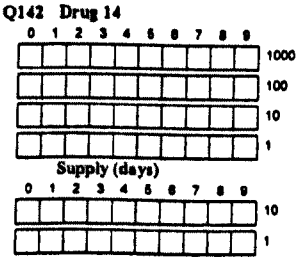
Q140 Drug 12



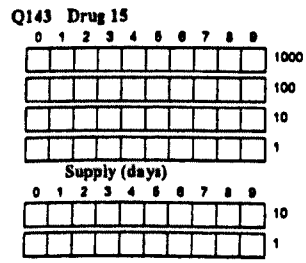
Q141 Drug 13



Q142 Drug 14



Q143 Drug 15



Q1 Study Number

INFUSIONS

Q2 CRYSTALLOID

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
N/saline 500mls x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
N/saline 100mls x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
D/saline 500mls x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Dextrose 5% 500mls x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dextrose 10% x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dextrose 20% x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dextrose 50% x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q5

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
N/saline + 20kcl 500mls x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
D/saline + 20kcl 500mlx1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5% Dextrose + 20kcl 500mls x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
20kcl x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
20kcl x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
20kcl x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
20kcl x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
20kclx5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q6

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Heparin/saline 500mls x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hartmanns soln 500mls x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q7 COLLOID

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Haemocell 500mls x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hespan 500mls x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
HAS 4.5% X1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
X2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
X3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
X4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
X5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
X6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
HAS 20% X1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
X2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Blood x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q8

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Platelets units x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Platelets pooled bag x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q9

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
FFP X1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FFPX2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Study Number

IV, IM & SC DRUGS
WEEKS 1&2

				1	2	3	4	5	6	7	8	9	10	11	12	13	14
Q2	Adenosine iv	1-6mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Adrenaline Bolus	1 in 1000	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Amoxycillin Injection	250mg TDS		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		500mg TDS		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Argipressin	5-20iu	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Q3	Atropine Sulphate	600mcg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Benzyll-penicillin	600mcg	BD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			QDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		1.2g	BD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			QDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Betamenthazone	4mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Q4	Calcium gluconate	10mg of 10%	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Calcium Chloride	10mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Cefotaxime	2g	TDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Cefuroxime	750mg	TDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		1.5g	TDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Ceftaxidime	1g	TDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		2g	BD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Chlorpheniramine	10mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Q5	Chlopromazine	25mg-50mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Co-Amoxiclav	1.2g	TDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Cyclizine	50mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

				1	2	3	4	5	6	7	8	9	10	11	12	13	14
Q6	Dexamethasone	4-8mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Dextrose	50% minijet	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Q7	Diazemuls	5-10mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		11-20mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Diclofenac	75mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Digoxin inj	125mcg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		250mcg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Droperidol	10mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Q8	Ergometrine	500mcg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Erythromycin	500mcg	QDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		1g	BD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Etomidate	Bolus	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Fleconide	150mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Q9	Flucloxacillin	250mg	QDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		500mg	QDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Flumazenil		x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Fruseimid@0mgs/2mls		x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Q10	Gentamicin	1-80mg	BD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			TDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		81-160mg	BD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			TDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Goserelin	3.6mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Glucagon	1 gm	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Glycopyronium	600mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

				1	2	3	4	5	6	7	8	9	10	11	12	13	14
Q11	Haloperidol	5mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Heparin s/c	5000u	BD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			TDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Heparin Infusion		x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Hydralazine	0-20mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Hydrocortisone	100mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		200mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Q12	Hyocine Butylbromide Buscapan	20mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Hyocine Hydrobromide	600mcg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Labetolol	50-100mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Leuprorelin	3.75mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Lorazepam	4mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Metaclopromide	10mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Methyl-prednisolone	120mg daily	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Q13	Naloxone	400mcg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Pabrinex I&II		OD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Phenytoin	100-250mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Phytomenadion	10mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Piperacillin	2g	QDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		4g	QDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Primaxin	500mg	BD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			TDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			QDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

				1	2	3	4	5	6	7	8	9	10	11	12	13	14
Q14	Prochlorperazine	12.5mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Promazine	50mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Protamine	up to 50mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Promethazine	25-50mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Ranitidine	50mg	TDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Tranexamic-acid	500mg	TDS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Vancomycin	500mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Verapermil	5mg	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Study Number

INVESTIGATIONS

Q2 Cardiac Tests

	PA	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 ECG	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2 ECGs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3 ECGs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4 ECGs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5ECGs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
more than 5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
24 hour tape	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
exercise ECG	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
echocardiogram	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q3 Endoscopies

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Bronchoscopy	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Colonoscopy	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ERCP	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Gastroscopy	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Sigmoidoscopy	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q4 X Rays

	PA	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Chest X-ray x 1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q5 X Rays

	PA	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Group A x 1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q6 X Rays

	PA	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Group B x 1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q7 X Rays

Group C x 1
x2

Q8 X Rays

GroupD x 1
Group E x1
Group F x1
Nuclear Med scan x1

X-Rays that are not found on list
Day_____

Test_____

X-Rays that are not found on list
Day_____

Test_____

Q9

Pregnancy Test
Urine Flow Studies

Q10
Test 1:
Day

Q11
Test 2:
Day

Q12
Test 3:
Day

Lines/Drains/Packs

Q13 Lines

Peripheral x1
x2
x3
x4

Central line x1
x2
x3

Tripple lumen x1
x2

Hickman
Swan ganz

Arterial
Epidural Catheter
Feeding line

Q14 Packs etc.
Vaginal pack
Nasal pack
Nasal pack splints

Q15 Drains

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Redivac x1
x2
x3
x4

Corrugated drain x1
x2

Robinson Portex Drain x1
x2
x3
x4

Chest Drain x1
x2
x3
x4

NG tube - bile drainage
T tube
Urinary Catheter
Re-catheterised
Suprapubic Catheter
Nephrostomy tube

Q16 Other

Tracheotomy Tube
ET Tube
Pacing Wire

Physiotherapy, OT, Speech Therapy etc

Q17 Physio - Face to Face contacts

1 2 3 4 5 6 7 8 9 10 11 12 13 14

x1
x2
x3
x4
x5
x6
x7
x8
x9
x10

Q18

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Dietician x1
Dietician x 2
Social worker
Speech therapy x1
x2
x3
Spec. stoma nrs
Macmillan Nrs
Diabetic Nrs Spec
Continence Nurse

Q19

OT	1	2	3	4	5	6	7	8	9	10	11	12	13	14
x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x7	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x8	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q20 OT Home Visit

Day of Visit 1

0 1 2 3 4 5 6 7 8 9 10
0 1 2 3 4 5 6 7 8 9 1

Day of Visit 2

0 1 2 3 4 5 6 7 8 9 10
0 1 2 3 4 5 6 7 8 9 1

Units supplied 1

0 1 2 3 4 5 6 7 8 9 1

Units supplied 2

0 1 2 3 4 5 6 7 8 9 1

Dressings/nursing procedures

Q21 Wound care

Number of wounds 0 1 2 3 4 5 6 7 8 9 1

Q22 Wound care

Wound redressed	1	2	3	4	5	6	7	8	9	10	11	12	13	14
X1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
X2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
X3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
X4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
X5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
>5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Stiches/clips removed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q23 Traction/Plaster/TEDS

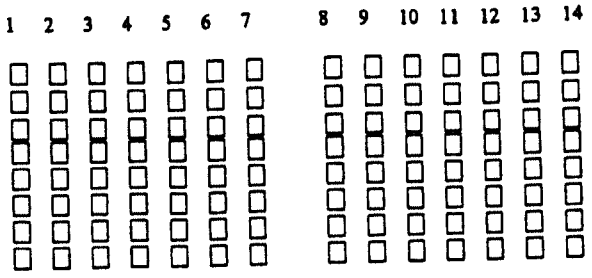
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Skin traction set up	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Check traction	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
c/o new plaster	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Limb plaster renewed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
TED stockings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CPM machine	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Nursing Care

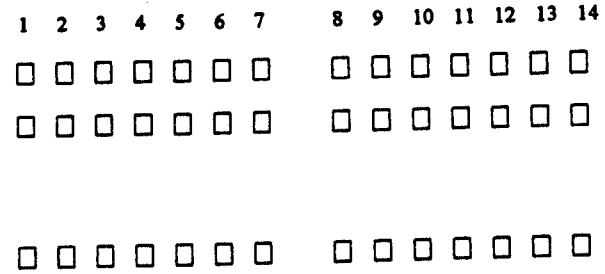
Q24 Personal Hygiene

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Bed Bath	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Assisted wash	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Full bath	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Assistance with dressing	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

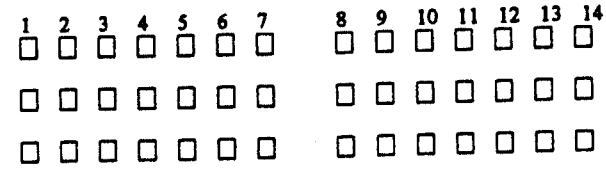
Q25 Elimination



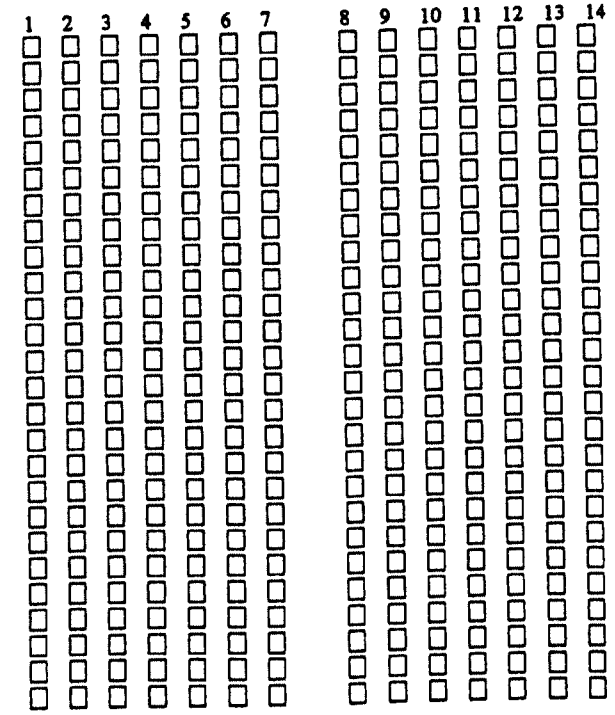
Q26 Prevention of presure sores, DVT etc



Q27 Mobility



Q28 Observations



Q29 Chest physio by nurse etc

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ET suction	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2-4 hourly chest physio	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
c/o oxygen therapy	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
c/o CPAP	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q30 Special Bed/mattress

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Foam/Spenco mattress	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ripple mattress	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Low air loss bed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Water/air fluidise bed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q31 Nutrition

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Help with fluids and meals	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Food chart maintained	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
c/o ng feed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
c/o TPN	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
c/o gastrostomy feed line	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Nutrison x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Teaching pt/relative education	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q32 Mental state/sensory defecits

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
c/o acute confusion	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
emotional support needed for pt +/or relatives	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
unconcious	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
impaired speech/sight/ hearing/language difficulties	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q33 Other

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cardio version	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cardiac arrest	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Barrier nursing	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q34 Haemofiltration/Dialysis

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Haemofiltration	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Set change x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Set change x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Set change x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dialyisis	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Study Number

OPERATION DATA

Operation 1

Q2 Day

Q3 Location

Anaesthetic Section

Q4 Anaesthetist 1 grade

Q5 Anaesthetist 2 grade

Q6 ASA grade

Q7 Anaesthetic type:

- ☐ GA only
- ☐ GA & LA
- ☐ LA +or- sedation
- ☐ Sedation only
- ☐ Epidural

Q8

- ☐ Local Infiltration
- ☐ Topical Infiltration
- ☐ Moffatt's solution
- ☐ Peripheral nerve block
- ☐ Intravenous regional
- ☐ Brachial plexus block
- ☐ Intercostal block
- ☐ Spinal
- ☐ Caudal epidural
- ☐ Lumbar epidural
- ☐ Thoracic epidural
- ☐ Cervical epidural

Surgical Section

Q9 Type of case:

- ☐ Elective
- ☐ Emergency
- ☐ Elective or urgent cases done by special arrangement (i.e. not on a routine list)

Q10 Urgency of Surgery:

- ☐ Within 1 hour
- ☐ Within 8 hours
- ☐ Within 24 hours
- ☐ Within 72 hours
- ☐ Within 3 weeks
- ☐ Non-urgent

Q11 Procedure 1: _____

OPCS4 code: _____

Letters

Numbers

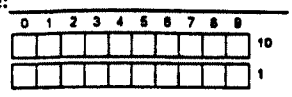
Q12 Grade of surgeon:

Q13 Grade of supervising surgeon:

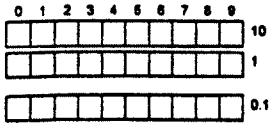
Q14 Procedure 2: _____

OPCS4 code: _____

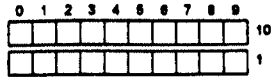
Letters



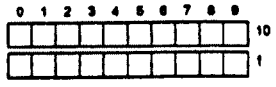
Numbers



Q15 Grade of surgeon:



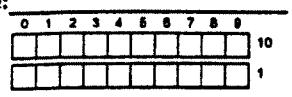
Q16 Grade of supervising surgeon:



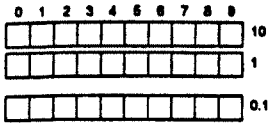
Q17 Procedure 3: _____

OPCS4 code: _____

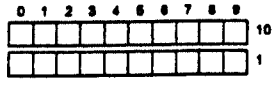
Letters



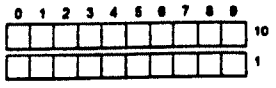
Numbers



Q18 Grade of surgeon:



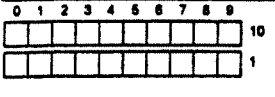
Q19 Grade of supervising surgeon:



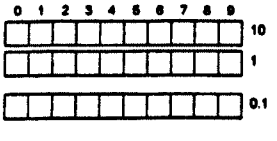
Q20 Procedure 4: _____

OPCS4 code: _____

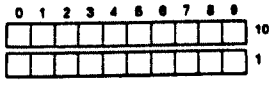
Letters



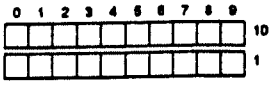
Numbers



Q21 Grade of surgeon:



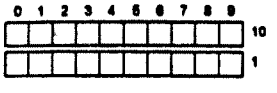
Q22 Grade of supervising surgeon:



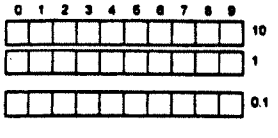
Q23 Procedure 5: _____

OPCS4 code: _____

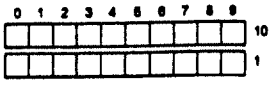
Letters



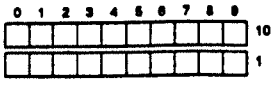
Numbers



Q24 Grade of surgeon:



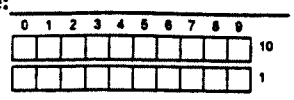
Q25 Grade of supervising surgeon:



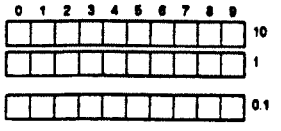
Q26 Procedure 6: _____

OPCS4 code: _____

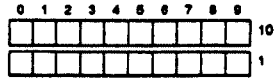
Letters



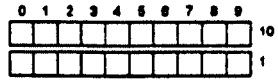
Numbers



Q27 Grade of surgeon:



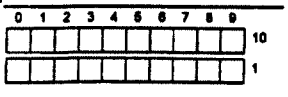
Q28 Grade of supervising surgeon:



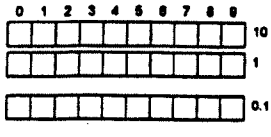
Q29 Procedure 7: _____

OPCS4 code: _____

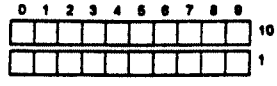
Letters



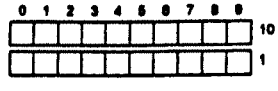
Numbers



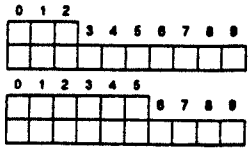
Q30 Grade of surgeon:



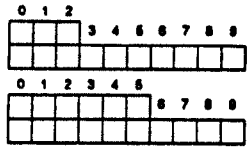
Q31 Grade of supervising surgeon:



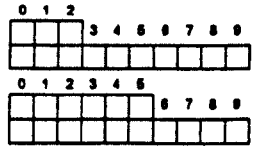
Q32 Time sent for:



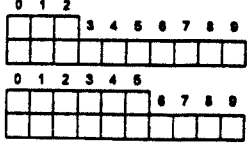
Q33 Time of induction:



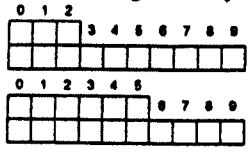
Q34 Time on table:



Q35 Time entering recovery:

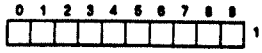


Q36 Time leaving recovery:

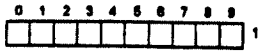


DRUGS IN THEATRE

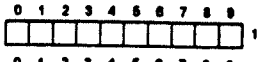
Q37 Augmentin 1.2 grams



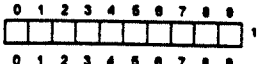
Cefuroxime 750mgs



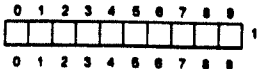
Cefuroxime 1.5grams



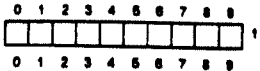
Erythromycin 1 grams



Gentamicin 80 mgs

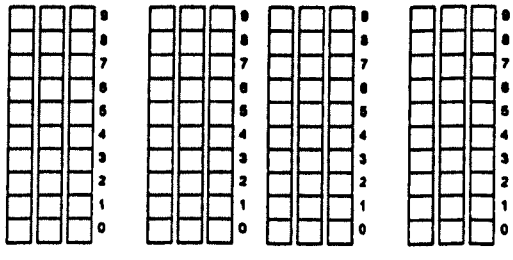


Gentamicin 120mgs



Metromidazole 500mgs

Q38 Other Antibiotics:



LAB TESTS: Day1-Day7

Study Number

Q2 Biochemistry, Haemotology, Histopathology & Cytopathology

		P/A	A&E	1	o/c	2	o/c	3	o/c	4	o/c	5	o/c	6	o/c	7	o/c
A1AT		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ABHB		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ADNA		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ALBU		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ALK P		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ALT		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
AMYL	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ANA		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
AST		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ATA		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BICA		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BILI		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BJP		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BM		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q3

CALC		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CE		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CHOL		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CK		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
COAGS	X1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
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	X3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
COMP		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CORT		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
COULT	X1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	X2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	X3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	X4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CREA		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CREA CL		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CRP		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DIFF		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DIGO		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ESR		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q4		P/A	A&E	1	o/c	2	o/c	3	o/c	4	o/c	5	o/c	6	o/c	7	o/c
FARA		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FBC	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	x4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FDP		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FE ST		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FL GLU		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FL PROT		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FOB		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FSH		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GASE		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GF		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GGT		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GLUC		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GLUC F		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GLYCA		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GTT		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GP		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q5				1	o/c	2	o/c	3	o/c	4	o/c	5	o/c	6	o/c	7	o/c
HBD		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
HEP	x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
IGA		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
IGE		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
IGG		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
IGM		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
IGS		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
INSU		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
IRON		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
KL		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LAP		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LFT		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LH		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LIB		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LITH		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Q6 MAGN		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
NA/K		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
OLIGO		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
OSMO		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PHENY		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PRC		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PROG		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PROL		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PROT		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PRS		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PSA		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q7

	P/A	A&E	1	o/c	2	o/c	3	o/c	4	o/c	5	o/c	6	o/c	7	o/c
RA	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
RC	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
RCF	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
RU BILI	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
RU CREA	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
RU NA/K	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
RU OSMO	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
RU PORP	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
RU UBG	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
RU UREA	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SB 12	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SCF GLU	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SFER	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SPE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SSP	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q8

TEST	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
THEO	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
THY	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
TRIG	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
U CALC	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
U CREA	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
U NA/K	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
U OXAL	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
U PHOS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
U PORP	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
U PROT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
U URAT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
U UREA	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
U VMA	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
U/E x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q9

URAT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
UREA	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
V CORT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
WARF	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
XM x1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
x2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q10

FS			☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2FS			☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2B			☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3B			☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4B			☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5B			☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6B			☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7B			☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8B			☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9B			☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
10B			☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Microbiology

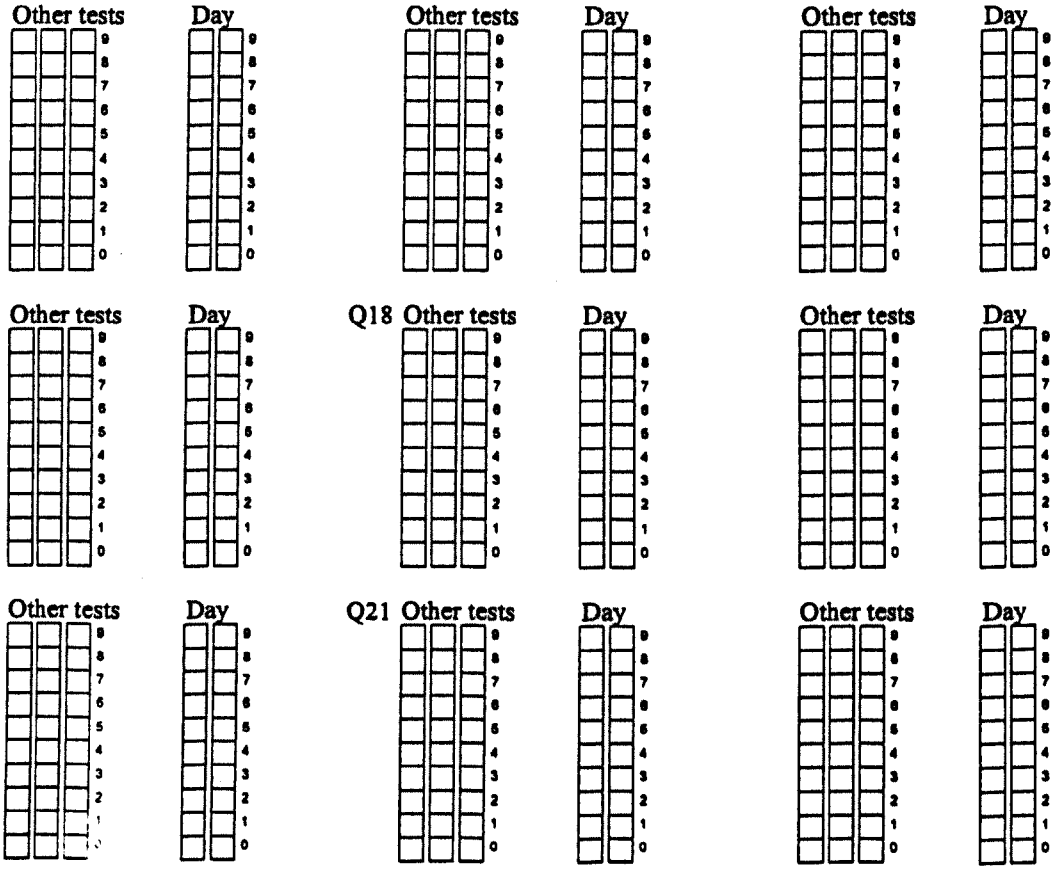
Q11

	P/A	A&E	1	o/c	2	o/c	3	o/c	4	o/c	5	o/c	6	o/c	7	o/c
AFB	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ASO	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
AWO	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BC	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CAPD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CHLAM	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CMV	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DIF	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DIS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
EAR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
EYE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FLUID	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FU	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GA	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GENT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GNT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q12

HAV	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
HBSAG	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
HEPC	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
HIV	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
HOLD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
HSV	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
IUC	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LEP	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LP	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MRSA	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
NS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PARV	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PEN	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PLEUR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PUS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q13	P/A	A&E	1	o/c 2	o/c 3	o/c 4	o/c 5	o/c 6	o/c 7	o/c
ROTA	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
RS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
RSV	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
S	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SP	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
STS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
TISSUF	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
TOXO	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
TS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
U	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
VAN	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
VI	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
VS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
VSER	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
W	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

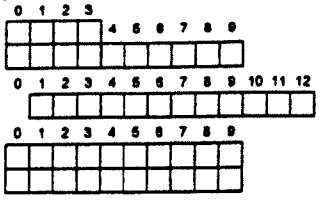


INFECTIONS

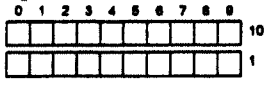
Study Number

Infection 1

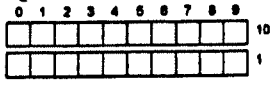
Q2 Date of onset:



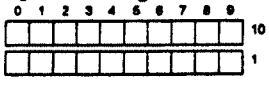
Q3 Site of infection:



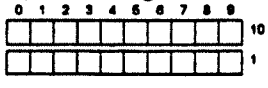
Q4 Device:



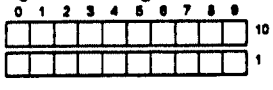
Q5 Pathogen 1:



Q6 Pathogen 2:



Q7 Pathogen 3:

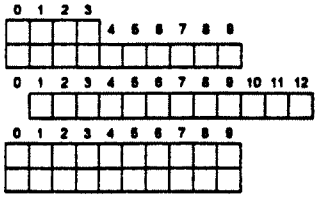


Q8

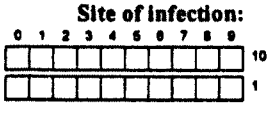
☐ CAI ☐ HAI - same ward ☐ HAI - different ward ☐ HAI - different hospital

Infection 2

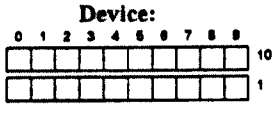
Q9 Date of onset:



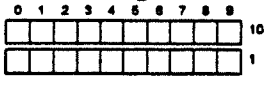
Site of infection:



Device:



Pathogen 1:



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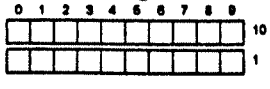

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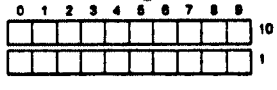
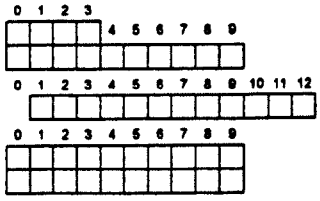


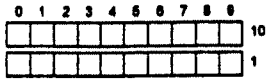
☐ CAI ☐ HAI - same ward ☐ HAI - different ward ☐ HAI - different hospital

Infection 3

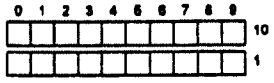
Date of onset:



Site of infection:



Device:



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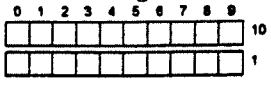
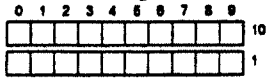
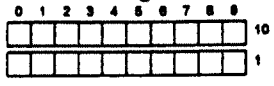


Pathogen 2:



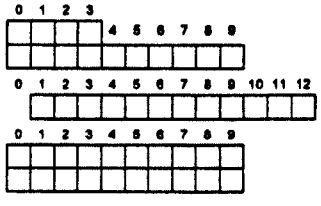
Pathogen 3:



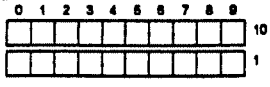
☐ CAI ☐ HAI - same ward ☐ HAI - different ward ☐ HAI - different hospital

Infection 4

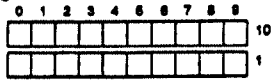
Q23 Date of onset:



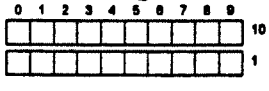
Q24 Site of infection:



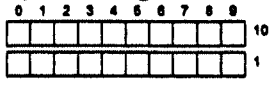
Q25 Device:



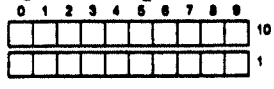
Q26 Pathogen 1:



Q27 Pathogen 2:



Q28 Pathogen 3:



Q29 ☐ CAI ☐ HAI - same ward ☐ HAI - different ward ☐ HAI - different hospital

Members of the Socio-economic Burden of Hospital Acquired Infection Project Team, Steering Committee and Advisory Group

A8.1 Introduction

This appendix provides details of the members of the Socio-economic Burden of Hospital Acquired Infection Project Team, Steering Committee, and Advisory Committee.

A8.2 Project Team

Rosalind Plowman BA, MSc, RN	Project Co-ordinator
Nicholas Graves, BA, MA	Research Economist
Mark Griffin, BA, MSc	Statistician
Rachael Dunk, RN	Research Assistant
Alison Franklin, BSc, RN	Research Assistant
Janette Trevarthen, RN, OHND	Research Assistant
Maggie Waters, RN	Research Assistant
Jennifer White, RN	Research Assistant
Lynda Wright, BSc, RN	Research Assistant
Barbara Ayres	Project Secretary
Christine Berry	Administrative support

A8.3 Project Steering Committee

Jane Bandcroft RN, DN, HV, FPCert	Director of Nursing Practice, Study Hospital
Barry Cookson MB, BDS, FRCP Path	Director of laboratory of Hospital Infection, Public Health Laboratiry Service
Helen Glenister BSc, PhD, RN	Nursing Director, Medical Devices Agency, DOH
Bernadette Nazareth MBBS, MSc, MRCPath	Consultant in Communicable Disease Control, Redbridge and Waltham Health Authority
Jennifer A Roberts MSc Econ, PhD, HMPHM	Reader in Economics of Public Health, London School of Hygiene and Tropical Medicine, London
Mike Rowland, MBBS, FRCP, FFPHM	Consultant Epidemiologist, Communicable Disease Surveillance Centre, Anglia and Oxford RHA
Tony Swan PhD, HMFPHM, C Stat	Director, Statistical Unit, Public Health Laboratory Service
Lynda Taylor, RN, RM	Head of Nursing and Infection Control Unit, Laboratory of Hospital Infection, Public Health Laboratory Service
Jennie Wilson, BSc, RN	Programme Leader Infection Control and Surveillance, Nursing and Infection Control Unit, laboratory of Hospital Infection, Public Health Laboratory Service

A8.4 Advisory Committee Members

Kay Butcher	Department of Health (to Oct 1995)
Millie Carter	Nursing Officer, Department of Health (to Sep 1994)
Sue Dewar RN, DNCert, MA	District Nurse, Chichester Primary Care Services Trust.
Georgia Duckworth MSc, FRCP, FRC Path, FRIPHH	Regional Epidemiologist, CDSC, North Thames
Johanna Finn BSc, MHSM, Dip HSM	Chief Executive, West Suffolk Hospitals Trust
Paul Gillett, MRCP, FRC Path	Consultant Medical Microbiologist, Stoke Mandeville Hospital
Simon Harding	Economic Advisor, Department of Health (to Sept 1995)
Jayne Holmes RN	Senior Nurse, Queen Elizabeth II Hospital, Welwyn Garden City (to Nov 1996)
Rosemary Jenkins MSc, DMS, MTD, RN, RM	Nursing Officer, Department of Health (from Sept 1994 to Sept 1995)
Bill Maton-Howarth PhD	Department of Health (from 1 April 1997)
Jennifer McIntyre RN, MSc	Nursing Officer, Department of Health (from Sept 1995)
Elizabeth Meerabeau BSc, PhD, RN, RHV, RNT, RHVT	Department of Health (to Mar 1997)
Richard Murray	Economic Advisor, Department of Health (from Sept 1995)
Elizabeth Tebbs MBBS, ChB	Senior Medical Officer, Department of Health
Ann Whittle	Department of Health (to Oct 1995)

Data variables included in the data analysis

A9.1 Introduction

This appendix provides further details regarding the variables included in the analysis of the incidence of HAI, and the impact HAIs had on hospital costs and length of hospital stay.

A9.2 Explanatory variables used in the regression analysis

A9.2.1 Overview of variables used

Table A9.1 provides details of the explanatory variables used in the data analysis.

A9.2.2 Admission type classification system

Patients were classified as being admitted via one of nine routes: elective via pre-admission, elective direct to the ward, urgent direct to the ward, emergency via the accident and emergency department, emergency via the out-patients department, emergency GP referral direct to the ward, transfer from another ward via the day hospital, transfer from another hospital and finally via another unspecified route. As indicated in Table A9.1, for the purpose of the analysis these nine admission types were compressed into three main categories: emergency admissions, elective admissions and transfers. Table A9.2 shows how the nine admission types were compressed into three main categories.

Table A9.1: Explanatory variables as used in the data analysis

Explanatory variable	Classification system
Sex	Male Female
Age	18 – 34 35 – 54 55- 74 75 +
Admission specialty	Surgery Orthopaedics Urology Gynaecology Obstetrics
Admission type*	Elective Emergency Transfer
Diagnosis group*	Primary discharge diagnosis grouped into one of 14 ICD9 categories
Number of co-morbidities	None One Two or more
Body Mass Index	BMI < 20 BMI 20-<30 BMI >30
Diabetes	Yes, No
Operation	Yes , No
Catheter present prior to UTI	Yes, No
Endotracheal tube present prior LRTI	Yes, No
Wound drain prior to SWI	Yes , No
Antibiotics administered prior to each type of infection	Yes, No
IV/IM antibiotics administered prior to each type of infection	Yes, No
HAI status	HAI identified during in-patient phase HAI not identified during the in- patient phase
Type of HAI*	HAIs were classified into 8 mutually exclusive groups: • no HAI • urinary tract infections • surgical wounds infections • lower respiratory tract infections • blood stream infections • skin infections • infections at other sites • multiple infections (infections at more than one site)

*Further details of the classification system used are presented below

Table A9.2: Admission type classification system

Admission categories used in the analysis	Admission types within each category
Elective	Elective via pre-admission clinic
	Elective
Emergency	Urgent direct to the ward
	Emergency via accident and emergency
	Emergency via out patients department
	GP referral
	Via day hospital
Transfers	Transfer from another ward
	Transfer from another hospital

A9.2.3 Primary diagnosis classification system

The primary discharge diagnosis were coded using the 9th revision of the International Classification of Diseases system (ICD9). Each primary discharge diagnosis was allocated either a three or four digit code depending on the amount of information available. These diagnosis were initially grouped into 19 disease categories according to the ICD9 classification system and then further compressed into 14 categories. Table A9.3 provides details of the ICD9 categories included in each of the 14 study categories.

Table A9.3: Diagnosis group classification system.

Study disease categories 1-14	ICD9 Disease categories included in study categories	Title of Categories
1	I	Infectious and parasitic disease
2	II	Neoplasms
3	III	Endocrine, nutritional and metabolic diseases, and immunity disorders
4	IV	Diseases of blood and blood forming organs
5	VI	Diseases of the nervous system and sense organs
6	V1I	Diseases of the circulatory system
7	VIII	Diseases of the respiratory system
8	IX	Diseases of the digestive system
9	X	Diseases of the genitourinary system
10	XI XV	Complications of pregnancy, childbirth and puerperium Certain conditions originating in the perinatal period
11	XII.	Diseases of the skin and subcutaneous tissue
12	XIII	Diseases of the musculoskeletal system and connective tissue
13	XVII	Injury and Poisoning
14	XVI V XIV	Symptoms, signs and ill- defined conditions Mental disorders Congenital abnormalities

A9.2.4 HAI classification system

HAIs identified during the in-patient phase were classified into eight mutually exclusive infection groups: no HAI, infections of the urinary tract, surgical wounds, lower respiratory tract, bloodstream, skin, other sites, and in those cases where patients acquired more than one infection, multiple infections. Table A9.4 provides details of the sites of infection included in the six single site infection groups.

Table A9.4: HAI classification system

HAI groups used in the analysis	Sites of infection included in the analysis groups*	No. of infections identified at each site	Percentage of infections identified at each site
Urinary tract infections	UTI Clinical	39	18.8
	UTI Clinical and laboratory evidence	61	29.3
	Asymptotic Bacteriuria	0	0.0
Lower respiratory tract infections	Pneumonia	10	4.8
	Chest Infection	13	6.3
	Lower respiratory tract	0	0.0
Surgical wound infections	Major SWI	6	2.9
	Minor SWI	34	16.3
Bloodstream infections**	Septicaemia	3	1.4
	Bacteraemia	1	0.5
Skin infections	Skin	15	7.2
	Skin Ulcers		0.0
	Pressure sores	1	0.5
	Blistered skin		0.0
Infections at other sites	Major accidental wound	1	0.5
	Minor accidental wound		0.0
	Upper respiratory tract and ear	2	1.0
	EYE		0.0
	Otitis externa	2	1.0
	Oral thrush	2	1.0
	Upper respiratory tract - unspecific	1	0.5
	Mouth	3	1.4
	Other genital tract	6	2.9
	GI	1	0.5
	Other abdominal	2	1.0
	Other	3	1.4
	Systemic	1	0.5
	Pericarditis	1	0.5

Note: Where more than one infection had been acquired these were classified as multiple infections

* Definitions of the infections listed can be found in Appendix 5

The age, sex, admission type and specialty distribution of study participants and eligible patients who were not recruited into the study

A10.1 Introduction

Between April 1994 and May 1995, 3534 patients admitted to the surgical specialties covered in this study were eligible for recruitment. Of these patients, 2477 (70.1%) patients were recruited into the study, 197 (5.6%) declined participation, 851 (24.1%) were not recruited due to practical reasons such as insufficient time, and in a further nine (0.3%) cases the reason for non-recruitment was not specified. In order to check how representative the study sample was of the wider eligible population the following data were recorded for all eligible patients who were not recruited: sex, age, admission type and admission specialty. The age, sex, admission type and specialty distributions of study participants and eligible patients who were not recruited into the study were subsequently analysed and compared. The results of this analysis are presented in this appendix.

A10.2 The distribution of study participants and eligible patients who were not recruited by sex

Table A10.1 provides details of the sex distribution of study participants and eligible patients who either declined participation, or were not recruited due to practical reasons such as insufficient time. Table A10.2 shows the sex distribution of study participants and eligible patients who were not recruited, together with that, which would have been present if all eligible patients had been recruited.

Table A10.1: Sex distribution of study patients and eligible patients who were not recruited

Sex	Study Participant		Reason for not recruiting eligible patients						All eligible patients not recruited	
			Patient declined participation		Patient not recruited due to practical reasons*		Reason for non-recruitment unknown			
	n.	%	n.	%	n	%	n	%	n	%
Male	1003	40.62	98	49.7	423	49.7	4	28.6	525	49.4
Female	1466	59.38	97	49.2	425	49.9	5	35.7	527	49.6
Unknown	0	0.0	2	1.0	3	0.4	5	35.7	10	0.9
TOTAL	2469	100	197		851		14		1062	

* For example insufficient time

Table A10.2: Sex distribution of study participants, eligible patients who were not recruited, and that which would have been present if all eligible patients were recruited

Eligible patients	Males	Females	All patients	Proportion (%) (95% CI) of male patients	P value
Recruited	1003	1466	2469	40.6 (38.7; 42.6)	<0.001
Not – recruited*	525	527	1052	49.9 (46.8; 53.0)	
All eligible patients	1528	1993	3521	43.4 (41.8; 45.1)	

*An additional 10 patients were not recruited however their sex was not recorded, consequently they have been excluded from this analysis

The percentage of male patients in the cohort of recruited patients was 8.3% higher than in the cohort of patients who were not recruited. This difference was found to be highly significant. However, the percentage of male patients in the recruited cohort was only 2.8% less than the intended cohort. This difference is extremely unlikely to lead to bias in estimates of how those with and without HAI compare.

A10.3 The distribution of study participants and eligible patients who were not recruited by age group

Table A10.3 provides details of the age distribution of study participants and eligible patients who either declined participation, or were not recruited due to practical reasons such as insufficient time. Table A10.4 shows the age distribution of study participants and all eligible patients who were not recruited, together with that which would have been present if all eligible patients had been recruited.

Table A10.3: Distribution of study participants and eligible patients who were not recruited by age group

Age Group	Study Participant		Reason for not recruiting eligible patients						All eligible Patients not recruited	
			Patient declined participation		Patient not recruited due to practical reasons*		Reason for non-recruitment unknown			
	n	%	n.	%	n	%	n.	%	n	%
18-30	363	14.7	15	7.6	79	9.3	1	11.1	95	9.0
31-40	337	13.6	17	8.6	91	10.7	2	22.2	110	10.4
41 - 50	336	13.6	13	6.6	127	14.9	1	11.1	141	13.3
51 - 60	375	15.2	43	21.8	174	20.4	1	11.1	218	20.6
61 - 80	915	37.1	80	40.6	244	28.7	3	33.3	327	30.9
81 - 100	143	5.8	28	14.2	60	7.1	1	11.1	89	8.4
Unknown		0.0	1	0.5	76	8.9	0	0.0	77	7.3
TOTAL	2469	100.0	197	100.0	851	100.0	9	100.0	1057	100.0

*For example insufficient time

Table A10.4: Age distribution of study participants, eligible patients who were not recruited, and that which would have been present if all eligible patients were recruited

Eligible patients	Age group		All patients	Proportion (%) of patients aged 18-60 (95% CI)	P value
	18-59	60+			
Recruited	1411	1058	2469	57.1 (55.2; 59.1)	0.8126
Not – recruited*	564	416	980	57.6 (54.4; 60.7)	
All eligible patients	1975	1474	3449	57.3 (55.6; 58.9)	

*An additional 77 patients were not recruited however their age was not recorded, consequently they have been excluded from this analysis

The results presented in Table A10.4 indicate that the proportion of study participants who were over 60 years of age was almost identical to that which would have been present if all eligible patients were recruited.

A10.4 The distribution of study participants and eligible patients who were not recruited by admission type

Table A10.5 provides details of the admission type distribution of study participants and eligible patients who either declined participation, or were not recruited due to practical reasons such as insufficient time. Table A10.6 shows the admission type distribution of study participants and all eligible patients who were not recruited, together with that which would have been present if all eligible patients had been recruited.

Table A10.5: Distribution of study participants and eligible patients who were not recruited by admission type

Admission Type	Study Participant		Reason for not recruiting eligible patients						All eligible Patients not recruited	
			Patient declined participation		Patient not recruited due to practical reasons*		Reason for non-recruitment unknown			
	n	%	n.	%	n	%	n	%	n	%
Elective	1629	66.0	118	59.9	421	49.5	4	44.4	543	51.4
Emergency	840	34.0	78	39.6	425	49.9	5	55.6	508	48.1
Unknown	0	0.0	1	0.5	5	0.6	0	0.0	6	0.6
TOTAL	2469	100.0	197	100.0	851	100.0	9	100.0	1057	100.0

*For example, insufficient time

Table A10.6: Admission type distribution of study participants, eligible patients who were not recruited, and that which would have been present if all eligible patients were recruited

Eligible patients	Admission type		All patients	Proportion (%) of patients who were elective admissions (95% CI)	P value
	Elective	Emergency			
Recruited	1629	840	2469	66.0 (64.1; 67.8)	<0.001
Not – recruited*	543	508	1051	51.7 (48.6; 54.7)	
All eligible patients	2172	1348	3520	61.7 (60.1; 63.3)	

The proportion of patients who were elective admissions differs significantly in the two cohorts: patients recruited into the study and eligible patients who were not recruited. However, the proportion of patients in the recruited cohort who were elective or emergency admissions only differed from the intended cohort by 4.3%. Again there is no reason to believe that differences of this magnitude will have led to substantial biases in comparisons of those with and without HAI.

A10.5 The distribution of study participants and eligible patients who were not recruited by admission specialty

Table A10.7 provides details of the distribution of study participants and eligible patients who either declined participation, or were not recruited due to practical reasons by admission specialty. Table A10.8 shows the admission specialty distribution of study participants and all eligible patients who were not recruited, together with that which would have been present if all eligible patients had been recruited.

Table A10.7: Distribution of study participants and eligible patients who were not recruited by admission specialty

Admission Specialty	Study Participant		Reason for not recruiting eligible patients						All eligible patients not recruited	
			Patient declined participation		Patient not recruited due to practical reasons*		Reason for non-recruitment unknown			
	n	%	n	%	n	%	n.	%	n	%
Surgery	884	35.8	73	37.1	468	55.0	3	33.3	544	51.5
Orthopaedics	501	20.3	45	22.8	121	14.2	5	55.6	171	16.2
Urology	472	19.1	60	30.5	186	21.9	0	0.0	246	23.3
Obstetrics & Gynaecology	612	24.8	19	9.6	76	8.9	1	11.1	96	9.1
TOTAL	2469	100	197	100.0	851	100.0	9	100.0	1057	100.0

*For example, insufficient time

Table A10.8: Admission specialty distribution of study participants, eligible patients who were not recruited, and that which would have been present if all eligible patients were recruited

Admission specialty	Eligible patients			Proportion (%) recruited from each specialty			P value
	Recruited	Not recruited	All eligible patients	Recruited	Not recruited	All eligible patients	
Surgery	884	544	1428	35.8	51.5	40.5	<0.001
Orthopaedics	501	171	672	20.3	16.2	19.1	
Urology	472	246	718	19.1	23.3	20.4	
Obstetrics & gynaecology	612	96	708	24.8	9.1	20.1	
All patients	2469	1057	3526	100.0	100.0	100.0	

The results presented in Table A10.8 indicate that there are significant differences in the proportion of patients from each specialty in the recruited and non-recruited patient groups. However, in no specialty was there more than a 4.7% difference between the recruited and intended cohort. There is therefore very little likelihood of these differences causing a substantial bias in the comparison between those who did and did not have HAIs.

A10.6 Conclusion

While the recruits and non-recruits had almost the same proportion of older patients, there were significantly more female patients and less emergency patients in the recruited cohort of patients, fewer surgical and urology patients and more orthopaedic and obstetric and gynaecology patients. However, the differences between the cohort of recruited patients and the intended cohort were quite small. Since the HAI and non HAI comparisons were stratified by all of these factors it is reasonable to assume that the results obtained from those recruited are generalisable to all eligible patients in the study hospital, despite the significant differences between those recruited and those not recruited.

The incidence of HAIs by primary operative procedure

A11.1 Introduction

This appendix presents the results of this analysis that examined the incidence of HAIs and how this varied with primary operative procedure. Tables A11.1 – A11.11 show how the incidence of HAI varied with primary operative procedure classified according to the Office of Population Census and Surveys operation classification system (fourth edition)[231] three-digit code. Where appropriate similar operations have been grouped together and the incidence of HAI calculated.

The incidence was found to vary with operative procedure. However the number of patients undergoing many of the specific procedures were small and as such, as evidenced by the confidence intervals, there is considerable uncertainty about the estimate derived.

The highest incidence of HAI occurred in patients whose primary procedure involved the female genital tract: 13.2% acquired one or more HAIs. Amongst these patients the incidence was highest in patients who had a repair of a prolapse of the vagina (19.3%), and hysterectomy (14.9%).

The second highest incidence rate was observed in patients whose primary procedure involved the arteries and veins: 8.9% of patients acquired one or more infections in hospital. Of these patients 33.3% of patients whose primary procedure involved the aorta and 25.0% of patients whose primary procedure involved the iliac and/or femoral artery acquired one or more infections that presented during the in-patient period. However, the number of patients in these two subgroups was small.

A similar incidence rate was observed in patients whose primary procedure involved the digestive tract: 8.9% acquired one or more infections that presented during the in-patient stay. The highest incidence rate was observed in patients who had a primary procedure which involved the ileum (57.1%); and patients who had a total or partial excision of the stomach and /or oesophagus (37.5%). Again the number of patients within the various sub-groups of procedures was small and as such strong conclusions cannot be drawn.

Table A11.1: The incidence of HAI occurring in patients whose primary operative procedure involved the nervous system, endocrine system, breast, respiratory tract or mouth

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Nervous system	A52	Therapeutic epidural injection	7	7	0	0.0	9	0	9	0.0
	A68	Other release of peripheral nerve	1	1	0	0.0				
	A81	Other operations on sympathetic nerve	1	1	0	0.0				
Thyroid and parathyroid gland	B08	Excision of thyroid gland	20	16	4	20.0	23	19	4	17.4
	B10	Operations on thyroglossal tissue	1	1	0	0.0				
	B14	Excision of parathyroid gland	2	2	0	0.0	81	81	0	0.0
Breast	B27	Total excision of breast	28	28	0	0.0				
	B28	Other excision of breast	40	40	0	0.0				
	B30	Prosthesis for breast	5	5	0	0.0				
	B31	Other plastic operations on breast	1	1	0	0.0				
	B32	Biopsy of breast	4	4	0	0.0				
	B33	Incision of breast	1	1	0	0.0				
	B34	Operations on duct of breast	2	2	0	0.0				
Exteriorisation of trachea	E42	Exteriorisation of trachea	1	0	1	100.0	-	-	-	-
Excision of lesion of tongue	F23	Excision of lesion of tongue	1	0	1	100.0	-	-	-	-
Excision of salivary gland	F44	Excision of salivary gland	6	6	0	0.0	-	-	-	

Table A11.2: The incidence of HAI occurring in patients whose primary operative procedure involved the digestive tract and other abdominal organs principally related to the digestive tract

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Excision of oesophagus and/or stomach	G01	Excision of oesophagus and stomach	3	1	2	66.7	8	5	3	37.5
	G27	Total excision of stomach	3	2	1	33.3				
	G28	Partial excision of stomach	2	2	0	0.0				
Other operations involving the oesophagus, duodenum and jejunum	G15	Other therapeutic fibreoptic endoscopic operations on oesophagus	1	1	0	0.0	7	3	1	14.3
	G24	Antireflux operations	2	2	0	0.0				
	G52	Operations on ulcer of duodenum	3	3	0	0.0				
	G59	Extirpation of lesion of jejunum	1	0	1	100.0				
Ileum	G69	Excision of ileum	2	0	2	100.0	7	3	4	57.1
	G74	Creation of artificial opening in ileum	1	0	1	100.0				
	G75	Attention to artificial opening into ileum	1	0	1	100.0				
	G76	Intraabdominal manipulation of ileum	1	1	0	0.0				
	G78	Other open operations on ileum	1	1	0	0.0				
	G82	Other operations on ileum	1	1	0	0.0				
Liver	J08	Therapeutic endoscopic operations on liver using laprascope	19	18	1	5.3	21	20	1	4.8
	J09	Diagnostic endoscopic examination of liver using laprascope	1	1	0	0.0				
	J13	Diagnostic percutaneous operations on liver	1	1	0	0.0				

Table A11.2 continued: The incidence of HAI occurring in patients whose primary operative procedure involved the digestive tract and other abdominal organs principally related to the digestive tract

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Gall bladder and bile duct	J18	Excision of gall bladder	53	50	3	5.7	55	51	4	7.3
	J19	Connection of gall bladder	1	1	0	0.0				
	J37	Other open operations on bile duct	1	0	1	100.0				
Pancreas and spleen	J65	Other open operations on pancreas	1	1	0	0.0	2	2	0	0.0
	J69	Total excision of spleen	1	1	0	0.0				
Appendix	H01	Emergency excision of appendix	36	35	1	2.8	41	40	1	2.4
	H02	Other excision of appendix	3	3	0	0.0				
	H04	Other operations on appendix	2	2	0	0.0				
Colon/caecum	H06	Extended excision of right hemi colon	1	1	0	0.0	28	25	3	10.7
	H07	Other excision of right hemi colon	7	7	0	0.0				
	H08	Excision of transverse colon	1	1	0	0.0				
	H09	Excision of left hemicolon	1	1	0	0.0				
	H10	Excision of sigmoid colon	8	7	1	12.5				
	H11	Other excision of colon	3	2	1	33.3				
	H14	Exteriorisation of caecum	1	1	0	0.0				
	H15	Other exteriorisation of colon	6	5	1	16.7				
Endoscopic procedures	H20	Endoscopic extirpation of lesion of colon	1	1	0	0.0	66	63	3	4.5
	H21	Other therapeutic endoscopic operations on colon	1	1	0	0.0				
	H22	Diagnostic endoscopic examination of colon	3	3	0	0.0				
	H25	Diagnostic endoscopic examination of lower bowel using fibreoptic sigmoidoscope	35	33	2	5.7				
	H26	Endoscopic extirpation of lesion of sigmoid colon using rigid sigmoidoscopy	3	2	1	33.3				
	H28	Diagnostic endoscopic examination of sigmoid colon using rigid sigmoidoscope	23	23	0	0.0				

Table A11.2 continued: The incidence of HAI occurring in patients whose primary operative procedure involved the digestive tract and other abdominal organs principally related to the digestive tract

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Rectum/anus	H33	Excision of rectum	16	12	4	25.0	87	81	6	6.9
	H36	Other abdominal operations for prolapse of rectum	2	2	0	0.0				
	H41	Other operations on rectum through anus	1	1	0	0.0				
	H42	Perineal operations for prolapse of rectum	1	1	0	0.0				
	H44	Manipulation of rectum	1	1	0	0.0				
	H48	Excision of lesion of anus	1	1	0	0.0				
	H49	Destruction of lesion of anus	1	1	0	0.0				
	H51	Excision of haemorrhoid	17	17	0	0.0				
	H52	Destruction of haemorrhoid	14	14	0	0.0				
	H54	Dilation of anal sphincter	1	1	0	0.0				
	H55	Other operations on perianal region	5	5	0	0.0				
	H56	Other operations on anus	11	10	1	9.1				
	H58	Drainage through perianal region	4	4	0	0.0				
	H59	Excision of pilonidal sinus	9	8	1	11.1				
	H60	Other operations on pilonidal sinus	3	3	0	0.0				

Table A11.3: The incidence of HAI occurring in patients whose primary operative procedure involved arteries and veins

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Aorta	L08	Transluminal operations on abnormality of great vessel	1	1	0	0.0	6	4	2	33.3
	L18	Emergency replacement of aneurysmal segment of aorta	1	1	0	0.0				
	L19	Other replacement of aneurysmal segment of aorta	2	1	1	50.0				
	L21	Other bypass of segment of aorta	1	1	0	0.0				
Iliac and femoral artery	L45	Reconstruction of other visceral branch of abdominal aorta	1	0	1	100.0	8	6	2	25.0
	L51	Other bypass of iliac artery	1	0	1	100.0				
	L62	Other open operations of femoral artery	2	1	1	50.0				
	L63	Transluminal operations on femoral artery	5	5	0	0.0				
Other arteriovenous operations	L75	Other arteriovenous operations	1	0	1	100.0	1	1	0	100.0
Varicose veins	L85	Ligation of varicose veins	25	25	0	0.0	40	40	0	0.0
	L87	Other operations on varicose vein of leg	15	15	0	0.0				
Therapeutic transluminal operations on vein	L94	Therapeutic transluminal operations on vein	1	1	0	0.0	1	1	0	0

Table A11.4: The incidence of HAI occurring in patients whose primary operative procedure involved the urinary system

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Kidney - procedures involving an incision	M02	Total excision of kidney	6.0	4	2	33.3	11	9	2	28.2
	M03	Partial excision of kidney	2.0	2	0	0.0				
	M05	Open repair of kidney	2.0	2	0	0.0				
	M06	Incision of kidney	1.0	1	0	0.0				
Kidney - endoscopic operations and/or percutaneous puncture of kidney	M09	Therapeutic endoscopic operations of calculus of kidney	5.0	4	1	20.0	9	8	1	11.1
	M10	Other therapeutic endoscopic operations of kidney	1.0	1	0	0.0				
	M11	Diagnostic endoscopic examination of kidney	1.0	1	0	0.0				
	M13	Percutaneous puncture of kidney	2.0	2	0	0.0				
Ureter - procedures involving an incision	M20	Replantation of ureter	2.0	2	0	0.0	4	4	0	0.0
	M23	Incision of ureter	2.0	2	0	0.0				
Ureter - endoscopic procedures	M37	Therapeutic ureterscopic operations on ureter	6.0	6	0	0.0	27	26	1	3.7
	M38	Other endoscopic removal of calculus from ureter	1.0	1	0	0.0				
	M39	Other therapeutic endoscopic operations on ureter	7.0	6	1	14.3				
	M320	Diagnostic endoscopic examination of ureter	11.0	11	0	0.0				
	M320	Operations of ureteric orifice	2.0	2	0	0.0				

Table A11.4 continued: Incidence of HAI occurring in patients whose primary operative procedure involved the urinary system

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Bladder - procedures involving an incision	M34	Total excision of bladder	2.0	2	0	0.0	8	7	1	12.5
	M35	Partial excision of bladder	1.0	1	0	0.0				
	M36	Enlargement of bladder	1.0	0	1	100.0				
	M38	Open drainage of bladder	3.0	3	0	0.0				
	M39	Other operations on contents of bladder	1.0	1	0	0.0				
Bladder - endoscopic procedures	M42	Endoscopic extirpation of lesion of bladder	60.0	57	3	5.0	157	149	8	5.1
	M43	Endoscopic operations to increase capacity of bladder	1.0	1	0	0.0				
	M44	Other therapeutic endoscopic operations on bladder	2.0	2	0	0.0				
	M45	Diagnostic endoscopic examination of bladder	92.0	87	5	5.4				
	M49	Other operations on bladder	2.0	2	0	0.0				
Outlet of female bladder	M51	Combined abdominal and vaginal operations to support outlet of female bladder	1.0	1	0	0.0	5	4	1	20.0
	M52	Abdominal operations to support our let of female bladder	4.0	3	1	25.0				
Prostate and outlet of male bladder - open procedures	M61	Open excision of prostate	4.0	3	1	25.0	6	5	1	16.7
	M64	Other open operations on outlet of male bladder	2.0	2	0	0.0				
Endoscopic operations on prostate and/or bladder	M65	Endoscopic resection of outlet of male bladder	82.0	76	6	7.3	111	104	7	6.3
	M66	Other therapeutic endoscopic operations on outlet of male bladder	9.0	9	0	0.0				
	M67	Other therapeutic endoscopic operations on prostate	4.0	4	0	0.0				
	M70	Other operations on outlet of male bladder	16.0	15	1	6.3				
Operations involving urethra	M73	Repair of urethra	1.0	1	0	0.0	16	15	1	6.3
	M76	Therapeutic endoscopic operations on urethra	7.0	7	0	0.0				
	M77	Diagnostic endoscopic examination of urethra	1.0	0	1	100.0				
	M79	Other operations on urethra	7.0	7	0	0.0				

Table A11.5: The incidence of HAI occurring in patients whose primary operative procedure involved the male genital organs

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Scrotum, testes and penis	N03	Other operations of scrotum	3	3	0	0.0	25	25	0	0.0
	N05	Bilateral excision of testes	1	1	0	0.0				
	N06	Other excision of testes	9	9	0	0.0				
	N08	Bilateral placement of testis in scrotum	1	1	0	0.0				
	N11	Operations on hydrocele sac	1	1	0	0.0				
	N13	Other operations on testes	2	2	0	0.0				
	N15	Operations on epididymis	2	2	0	0.0				
	N28	Plastic operations on penis	1	1	0	0.0				
	N29	Prosthesis of penis	1	1	0	0.0				
	N30	Operations on prepuce	4	4	0	0.0				

Table A11.6: The incidence of HAI occurring in patients whose primary operative procedure involved the female genital organs

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Vulva	P05	Excision of vulva	1	1	0	0.0	2	2	0	0.0
	P09	Other operations on vulva	1	1	0	0.0				
Extirpation of lesion of vagina	P20	Extirpation of lesion of vagina	1	1	0	0.0	1	0	1	0.0
Vagina - repair of prolapse	P22	Repair of prolapse of vagina and amputation of cervix uteri	2	2	0	0.0	57	46	11	19.3
	P23	Other repair of prolapse of vagina	55	44	11	20.0				
Hysterectomy	Q07	Abdominal excision of uterus	105.0	89	16	15.2	174	148	26	14.9
	Q08	Vaginal excision of uterus	69.0	59	10	14.5				
Other operations involving uterus, fallopian tubes, cervix and ovaries	Q02	Destruction of lesion of cervix uteri	1	0	1	0.0	53	50	3	5.7
	Q03	Biopsy of cervix	0	3.0	3	0.0				
	Q05	Other operations on cervix uteri	0	1.0	1	0.0				
	Q09	Other open operations on uterus	0	2.0	2	0.0				
	Q10	Curettage of uterus	0	6.0	6	0.0				
	Q12	Removal of intrauterine contraceptive device	0	1.0	1	0.0				
	Q22	Bilateral excision of adnexa of uterus	0	6.0	6	0.0				
	Q23	Unilateral excision of adnexa of uterus	0	11.0	11	0.0				
	Q25	Partial excision of fallopian tube	0	1.0	1	0.0				
	Q29	Open reversal of female sterilisation	0	3.0	3	0.0				
	Q30	Salpingostomy	1	2.0	1	50.0				
	Q34	Other open operations on fallopian tubes	0	1.0	1	0.0				
	Q41	Other operations on fallopian tubes	0	2.0	2	0.0				
	Q43	Partial excision of ovary	1	5.0	4	20.0				
	Q47	Other open operations on ovary	1	8.0	7	12.5				

Table A11.6 continued: The incidence of HAI occurring in patients whose primary operative procedure involved the female genital organs

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Diagnostic endoscopic examinations	Q18	Diagnostic endoscopic examination of uterus	11.0	11	0	0.0	14	14	0	0.0
	Q39	Diagnostic endoscopic examination of fallopian tubes	3.0	3	0	0.0				
Hysterectomy	Q07	Abdominal excision of uterus	105.0	89	16	15.2	174	148	26	14.9
	Q08	Vaginal excision of uterus	69.0	59	10	14.5				
Other operations involving uterus, fallopian tubes, cervix and ovaries	Q02	Destruction of lesion of cervix uteri	1	1	0	0.0	53	50	3	5.7
	Q03	Biopsy of cervix	3.0	3	0	0.0				
	Q05	Other operations on cervix uteri	1.0	1	0	0.0				
	Q09	Other open operations on uterus	2.0	2	0	0.0				
	Q10	Curettage of uterus	6.0	6	0	0.0				
	Q12	Removal of intrauterine contraceptive device	1.0	1	0	0.0				
	Q22	Bilateral excision of adnexa of uterus	6.0	6	0	0.0				
	Q23	Unilateral excision of adnexa of uterus	11.0	11	0	0.0				
	Q25	Partial excision of fallopian tube	1.0	1	0	0.0				
	Q29	Open reversal of female sterilisation	3.0	3	0	0.0				
	Q30	Salpingostomy	2.0	1	1	50.0				
	Q34	Other open operations on fallopian tubes	1.0	1	0	0.0				
	Q41	Other operations on fallopian tubes	2.0	2	0	0.0				
	Q43	Partial excision of ovary	5.0	4	1	20.0				
	Q47	Other open operations on ovary	8.0	7	1	12.5				

Table A11.7: The incidence of HAIs occurring in patients whose primary operative procedure code involved the female genital tract associated with pregnancy and birth

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Caesarean sections	R17.2	Elective caesarean delivery	91	83	8	8.8	212	192	20	9.4
	R18.2	Other caesarean delivery	121	109	12	9.9				
	R28.2	Instrumental removal o products of conception from delivered uterus	1	0	1	0.0	1	0	1	0.0
Other operations	R12.1	Operations on gravid uterus	1	0	1	0.0				

Table A11.8: The incidence of HAI occurring in patients whose primary operative procedure involved the skin

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Skin	S04	Other excision of skin	1	1	0	0	21	19	2	9.5
	S06	Other excision of lesion of skin	5	4	1	20				
	S15	Other biopsy of skin	3	3	0	0				
	S18	Distant flap of skin and fascia	1	1	0	0				
	S42	Suture of skin of other site	2	2	0	0				
	S45	Removal of other substance of skin	1	1	0	0				
	S47	Opening of skin	5	4	1	20				
	S57	Exploration of other skin of other site9.5	3	3	0	0				

Table A11.9: The incidence of HAI occurring in patients whose primary operative procedure code involved soft tissue

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Pleura	T12	Puncture of pleura	5	0	5	0.0	5	0	5	0
Inguinal, femoral and umbilical hernia	T19	Simple excision of inguinal hernia	1	1	0	0.0	147	139	8	5.5
	T20	Primary repair of inguinal hernia	96	95	1	1.0				
	T21	Repair of recurrent inguinal hernia	6	6	0	0.0				
	T22	Primary repair of femoral hernia	2	1	1	50.0				
	T24	Repair of umbilical hernia	13	13	0	0.0				
	T25	Primary repair of incisional hernia	7	7	0	0.0				
	T27	Repair of other hernia of abdominal wall	5	5	0	0.0				
Abdomen, peritoneum, omentum.	T30	Opening of abdomen	17	11	6	35.3	33	24	33	27.3
	T34	Open drainage of peritoneum	1	1	0	0.0				
	T36	Operations on omentum	1	0	1	100.0				
	T41	Other open operations on peritoneum	2	1	1	50.0				
	T43	Diagnostic endoscopic examination of peritoneum	7	7	0	0.0				
	T52	Excision of fascia	2	1	1	50.0				
	T55	Release of fascia	1	1	0	0.0				
	T62	Operations on bursa	1	1	0	0.0				
	T79	Repair of muscle	1	1	0	0.0				
Other operations	T85	Block dissection of lymph nodes	4	4	0	0.0	10	0	10	0.0
	T87	excision of biopsy of lymph node	3	3	0	0.0				
	T94	Operations on bronchial cleft	1	1	0	0.0				
	T96	Other operations on soft tissue	2	2	0	0.0				

Table A11.10: The incidence of HAI occurring in patients whose primary operative procedure involved bones and joints

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Lumbar spine	V25	Primary decompression operations on lumbar spine	3	3	0	0	15	0	15	0
	V33	Primary excision of lumbar intervertebral disc	12	12	0	0				
Excision/division/fracture of bone	W6	Total excision of bone	3	3	0	0.0	29	2	27	6.9
	W8	Other excision of bone	4	4	0	0.0				
	W9	Extirpation of lesion of bone	2	2	0	0.0				
	W10	Open surgical fracture of bone	1	0	1	100.0				
	W11	Other surgical fracture of bone	1	1	0	0.0				
	W12	Angulation periarticular division of bone	3	2	1	33.3				
	W14	Diaphyseal division of bone	1	1	0	0.0				
	W15	Division of bone of foot	13	13	0	0.0				
	W16	Other division of bone	1	1	0	0.0				
Reduction of fracture	W19	Primary open reduction of fracture of bone and intramedullary fixation	22	20	2	9.1	87	82	5	5.7
	W20	Primary open reduction of fracture of bone and extramedullary fixation	26	25	1	3.8				
	W21	Primary open reduction of intraarticular fracture of bone	6	6	0	0.0				
	W22	Other primary open reduction of fracture of bone	2	2	0	0.0				
	W24	Closed reduction of fracture of bone and internal fixation	17	17	0	0.0				
	W26	Other closed reduction of fracture of bone	3	3	0	0.0				
	W28	Other internal fixation of bone	7	6	1	14.3				
	W32	Other graft of bone	1	1	0	0.0				
	W35	Therapeutic puncture of bone	3	2	1	33.3				

Table A11.10 continued: The incidence of HAI occurring in patients whose primary operative procedure involved bones and joints

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Hip replacement	W37	Total prosthetic replacement of hip joint using cement	85	7	92	7.6	103	96	7	6.8
	W38	Total prosthetic replacement of hip joint not using cement	10	0	10	0.0				
	W39	Other total prosthetic replacement of hip joint	74	69	5	6.8				
Knee replacement	W40	Total; prosthetic replacement of knee joint using cement	4	4	0	0.0	82	76	6	7.3
	W41	Total prosthetic replacement of knee joint not using cement	4	3	1	25.0				
	W42	Other prosthetic replacement of knee joint								
Replacement of other joint	W44	Total prosthetic replacement other joint not using cement	2	1	1	50.0	3	2	1	33.3
	W45	Other total prosthetic replacement of other joint	1	1	0	0.0				
Replacement of head of femur/humerus	W46	Prosthetic replacement of head of femur using cement	2	0	2	100.0	19	17	2	10.5
	W47	Prosthetic replacement of head of femur not using cement	9	9	0	0.0				
	W49	Prosthetic replacement of head of humerus using cement	2	2	0	0.0				
	W50	Prosthetic replacement of head of humerus not using cement	4	4	0	0.0				
	W51	Other prosthetic replacement of head of humerus	1	1	0	0.0				
	W52	Prosthetic replacement of articulation of other bone using cement	1	1	0	0.0				
Reconstruction/fusion of joint	W55	Prosthetic interposition reconstruction of joint	1	1	0	0.0	11	0	11	0
	W57	Other interposition reconstruction of joint	8	8	0	0.0				
	W59	Fusion of joint of toe	1	1	0	0.0				
	W60	Fusion of other joint and extraarticular bone graft	1	1	0	0.0				
Reduction of traumatic dislocation	W65	Primary open reduction of traumatic dislocation of joint	1	0	1	0.0	8	0	8	0
	W66	Primary closed reduction of traumatic dislocation of joint	7	0	7	0.0				

Table A11.10 continued: The incidence of HAI occurring in patients whose primary operative procedure code involved bones and joints

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR(%)	n	No HAI	HAI	%
Open operations on ligaments of joints	W70	Open operations on semilunar cartilage	1	1	0	0.0	20	18	2	10.0
	W72	Prosthetic replacement of ligament	5	5	0	0.0				
	W77	Stabalising operations of joint	3	3	0	18.2				
	W81	Other open operations on joint	11	9	2	0.0				
Endoscopic operations on joints	W82	Therapeutic endoscopic operations on semilunar cartilage	3	3	0	0.0	11	0	11	0.0
	W84	Therapeutic endoscopic operations on other joint structure	1	1	0	0.0				
	W85	Therapeutic endoscopic operations on cavity of knee joint	2	2	0	0.0				
	W87	Diagnostic endoscopic examination of knee joint	3	3	0	0.0				
	W88	Diagnostic endoscopic examination of other joint	1	1	0	0.0				
	W90	Puncture of joint	1	1	0					
Manipulation of joint	W91	Other manipulation on joint	1	0	1	0.0	1	0	1	0.0

Table A11.11: The incidence of HAI occurring in patients whose primary operative procedure involved other miscellaneous operations not classified elsewhere

Operations involving:	Code	Category	Individual procedures				Combined category			
			n	No HAI	HAI	IR (%)	n	No HAI	HAI	%
Amputation of hand leg or toe	X08	Amputation of hand	2	2	0	0.0	8	5	3	37.5
	X09	Amputation of leg	2	0	2	100				
	X11	Amputation of toe	3	2	1	33.3				
	X23	Correction of congenital deformity of leg	1	1	0	0.0				
Miscellaneous	X03	Replacement of other organ	1	1	0	0.0	9	0	9	0.0
	Y06	Excision of lesion of organ nec	1	1	0	0.0				
	Y22	Drainage or organ nec	1	1	0	0.0				
	Y30	Incision of organ noc	1	1	0	0.0				
	Y50	Approach through abdominal cavity	5	5	0	0.0				

Results of the analysis that assessed how hospital costs varied with site of infection and selected patient characteristics

A12.1 Introduction

The results of the analysis that assessed how hospital costs varied with site of infection and selected patient characteristics are presented in this appendix.

The results presented in tables A12.1 - A12.7 show that whilst for all sites of infection hospital costs, on average, are higher in infected than uninfected patients for all the patient characteristics examined, the level of increase varied with type of infection. However, it should be noted that in some cases the number of patients in the infected groups was small and as such the results cannot be generalized.

Table A12.1: Mean in-patient hospital costs for patients with a urinary tract infection compared with those incurred by uninfected patients by key patient characteristics

Patient characteristic	Mean hospital costs (£)				Ratio of costs (95% CI)	Additional Costs (£) (95% CI)
	No HAI		UTI only			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	1439	946	3148	18	2.2 (1.0, 3.4)	1709 (1034, 2383)
Female	1810	1330	2781	70	1.5 (1.2, 1.8)	971 (612, 1331)
Age group						
18 –34	1672	485	2614	15	1.6 (1.3, 1.8)	942 (234, 1651)
35-54	1509	627	2146	26	1.4 (1.2, 1.6)	636 (122, 1150)
55-74	1636	870	2908	32	1.8 (1.2, 2.4)	1272 (736, 1807)
75+	1997	294	4218	15	2.1 (0.9, 3.3)	2221 (1284, 3159)
Specialty						
General surgery	1338	829	5440	10	4.1 (1.0, 7.1)	4102 (2934, 5271)
Orthopaedics	2157	462	4330	12	2.0 (1.4, 2.6)	2173 (1421, 2926)
Urology	1316	445	1952	17	1.5 (1.2, 1.8)	636 (222, 1051)
Gynaecology	1682	336	2102	36	1.2 (1.1, 1.4)	420 (176, 664)
Obstetrics	2508	204	2779	13	1.1 (0.5, 1.7)	271 (-648, 1190)
Admission type						
Elective	1569	1519	2061	58	1.3 (1.2, 1.4)	492 (178, 806)
Emergency	1828	757	4392	30	2.4 (1.6, 3.2)	2564 (1873, 3255)
Discharge diagnosis group						
Infectious & parasitic diseases	867	12	940	1	1.1 *	73 *
Neoplasms	1714	329	2563	14	1.5 (1.1, 1.9)	850 (85, 1615)
Endocrine, nutritional & metabolic diseases & immunity disorders	1360	20	—	0	—	—
Diseases of blood & blood forming organs	992	3	—	0	—	—
Diseases of the nervous system & sense organs	712	2	—	0	—	—
Diseases of the circulatory system	1134	142	19781	1	17.4 *	18647 *
Diseases of the respiratory system	1726	4	—	0	—	—
Diseases of the digestive system	1249	396	2007	7	1.6 (1.0, 2.2)	759 (-505, 2023)
Diseases of the genitourinary system	1501	519	2061	34	1.4 (1.2, 1.5)	560 (255, 856)
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	2382	230	2612	15	1.1(0.8, 1.2)	230 (-854, 713)
Diseases of the skin & subcutaneous tissue	951	28	—	0	—	—
Diseases of the musculoskletal system & connective tissue	2176	296	2904	3	1.3 (1.0, 1.7)	728 (-613, 2070)
Injury & Poisoning	2136	160	4806	9	2.2 (1.4, 3.1)	2670 (1674, 3666)
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	1189	135	4865	4	4.1(1.9, 10.1)	3676 (2127, 5225)
Number of co-morbidities						
None	1582	1532	247	56	1.6 (1.2, 2.0)	894 (552, 1232)
One	1723	528	2669	24	1.5 (1.2, 1.9)	946 (255, 1638)
Two	2012	216	6082	8	3.0 (1.4, 4.7)	4069 (2590, 5548)

UTI – urinary tract infection. *Numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

Table A12.2: Mean in-patient hospital costs for patients with a surgical wound infection compared with those incurred by uninfected patients by key patient characteristics

Patient characteristic	Mean hospital costs (£)				Ratio of costs (95% CI)	Additional costs (£) (95% CI)
	No HAI		SWI only			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	1439	946	4108	15	2.9 (1.1, 4.6)	2669(974, 4364)
Female	1810	1330	2366	17	1.3 (0.9, 1.8)	556 (-234, 1347)
Age group						
18 –34	1672	485	3788	7	2.3 (0.8, 3.7)	2116 (1050, 1868)
35-54	1509	627	2070	4	1.4 (0.7, 2.1)	561 (-747, 1868)
55-74	1636	870	2865	16	1.8 (1.2, 2.3)	1228 (506, 1951)
75+	1997	294	4242	5	2.1 (1.0, 3.30	2245 (876, 3613)
Specialty						
General surgery	1338	829	3325	12	2.5 (1.6, 3.4)	1988 (1000, 2796)
Orthopaedics	2157	462	3612	11	1.7 (0.9, 2.5)	1455 (658, 2252)
Urology	1316	445	4525	2	3.4 (0.1, 6.9)	3208(2000, 4416)
Gynaecology	1682	336	1473	4	0.9 (0.4, 1.3)	-208 (-921, 504)
Obstetrics	2508	204	2421	3	1.0 (0.7, 1.2)	-88 (-1840, 1665)
Admission type						
Elective	1569	1519	2715	16	1.7 (1.3, 2.2)	1146 (547, 1744)
Emergency	1828	757	3650	16	2.0 (1.2, 2.8)	1822 (936, 2707)
Discharge diagnosis group						
Infectious & parasitic diseases	867	12	—	0	—	—
Neoplasms	1714	329	3929	3	2.3 (1.6, 3.0)	2216 (579, 3833)
Endocrine, nutritional & metabolic diseases & immunity disorders	1360	20	1164	1	0.9 *	-197 *
Diseases of blood & blood forming organs	992	3	—	0	—	—
Diseases of the nervous system & sense organs	712	2	—	0	—	—
Diseases of the circulatory system	1134	142	3451	1	3.0 *	2317 *
Diseases of the respiratory system	1726	4	—	0	—	—
Diseases of the digestive system	1249	396	3073	4	2.5 (1.0, 3.9)	1825 (149, 3501)
Diseases of the genitourinary system	1501	519	4339	2	2.9 (0.4, 6.2)	2838 (1571, 4104)
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	2382	230	2421	3	1.0 (0.7, 1.3)	38 (-699, 1775)
Diseases of the skin & subcutaneous tissue	951	28	1656	1	1.7 (1.3, 2.2)	706 (-556, 1968)
Diseases of the musculoskletal system & connective tissue	2176	296	2762	5	1.3 (0.9, 1.6)	586 (-4456, 1628)
Injury & Poisoning	2136	160	3108	10	1.5 (0.5, 2.4)	972 (-30, 1973)
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	1189	135	5331	2	4.5 (04.4, 9.4)	4142 (2489, 5795)
Number of co-morbidities						
None	1582	1532	2331	18	1.5 (1.0, 2.0)	749 (187, 1312)
One	1723	528	3749	10	2.2 (1.3, 3.0)	2027 (958, 3095)
Two	2012	216	5596	4	2.8 (1.3, 4.2)	3584 (1655, 5512)

SWI - surgical wound infection

*Numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

Table A12.3: Mean in-patient hospital costs for patients with a lower respiratory tract infection compared with those incurred by uninfected patients by key patient characteristics

Patient characteristic	Mean hospital costs (£)				Ratio of costs (95% CI)	Additional Costs (£) (95% CI)
	No HAI		LRTI			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	1439	946	5450	9	3.8 (1.3, 6.3)	4011 (1778, 6244)
Female	1810	1330	2613	6	1.4 (0.8, 2.1)	804 (-435, 2042)
Age group						
18 –34	1672	485	4693	1	2.8 *	3022 *
35-54	1509	627	2081	2	1.4 (1.1. 1.7)	572 (-1274, 2418)
55-74	1636	870	5553	7	3.4 (1.4, 5.3)	3917 (2809, 5024)
75+	1997	294	3400	5	1.7 (0.8, 2.7)	1403 (41, 2764)
Specialty						
General surgery	1338	829	5068	10	3.8 (2.0, 5.6)	3730 (2630, 4830)
Orthopaedics	2157	462	2825	2	1.3 (1.1, 1.5)	668 (-1106, 2442)
Urology	1316	445	1392	1	1.1 *	76 *
Gynaecology	1682	336	2313	1	1.4 *	632 *
Obstetrics	2508	204	4693	1	1.9 *	2185 *
Admission type						
Elective	1569	1519	4820	8	3.1 (1.5,4.6)	3251 (2395, 4107)
Emergency	1828	757	3738	7	2.0 (0.7, 3.4)	1910 (589, 3230)
Discharge diagnosis group						
Infectious & parasitic diseases	867	12	—	0	—	—
Neoplasms	1714	329	7143	3	4.2 (1.1, 7.2)	5430 (3746, 7113)
Endocrine, nutritional & metabolic diseases & immunity disorders	1360	20	4389	1	3.2 *	3028 *
Diseases of blood & blood forming organs	992	3	—	0	—	—
Diseases of the nervous system & sense organs	712	2	—	0	—	—
Diseases of the circulatory system	1134	142	—	0	—	—
Diseases of the respiratory system	1726	4	10738	1	6.2 *	9013 *
Diseases of the digestive system	1249	396	1891	4	1.5 (1.0, 2.0)	643 (-1027, 2312)
Diseases of the genitourinary system	1501	519	2313	1	1.5*	813*
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	2382	230	4693	1	2.0*	2311*
Diseases of the skin & subcutaneous tissue	951	28	—	0	—	—
Diseases of the musculoskletal system & connective tissue	2176	296	2825	2	1.3 (1.1, 1.5)	649 (-992, 2290)
Injury & Poisoning	2136	160	—	0	—	—
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	1189	135	3974	2	3.3 (0.9, 7.6)	2785 (1150, 4421)
Number of co-morbidities						
None	1582	1532	2788	5	1.8 (1.0, 2.5)	1206 (149, 2263)
One	1723	528	4760	3	2.8 (1.6, 3.9)	3038 (1106, 4970)
Two	2012	216	5215	7	2.6 (0.9, 4.3)	3203 (1704, 4701)

LRTI – lower respiratory tract infection

*Numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

Table A12.4: Mean in-patient hospital costs for patients with a bloodstream infection compared with those incurred by uninfected patients by key patient characteristics

Patient characteristic	Mean hospital costs (£)				Ratio of costs (95% CI)	Additional Costs (£) (95% CI)
	No HAI		BSI			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	1439	946	8953	3	6.2 (0.2, 12.3)	7514 *
Female	1810	1330	---	0	---	---
Age group						
18 –34	1672	485	15937	1	9.5 *	14265 *
35-54	1509	627	8263	1	5.5 *	6753 *
55-74	1636	870	2660	1	1.6 *	1024 *
75+	1997	294	---	0	--	---
Specialty						
General surgery	1338	829	8263	1	6.2 *	6925 *
Orthopaedics	2157	462	15937	1	7.4 *	13779 *
Urology	1316	445	2660	1	2.0 *	1344 *
Gynaecology	1682	336	---	0	---	---
Obstetrics	2508	204	---	0	---	---
Admission type						
Elective	1569	1519	2660	1	1.7 *	1091 *
Emergency	1828	757	12100	2	6.6 (2.5, 10.8)	10271 (7818, 12724)
Discharge diagnosis group						
Infectious & parasitic diseases	867	12	---	0	---	---
Neoplasms	1714	329	---	0	---	---
Endocrine, nutritional & metabolic diseases & immunity disorders	1360	20	---	0	---	---
Diseases of blood & blood forming organs	992	3	---	0	---	---
Diseases of the nervous system & sense organs	712	2	---	0	---	---
Diseases of the circulatory system	1134	142	---	0	---	---
Diseases of the respiratory system	1726	4	15937	1	9.2 *	14211 *
Diseases of the digestive system	1249	396	8263	1	6.6 *	7014 *
Diseases of the genitourinary system	1501	519	2660	1	1.8 *	1160 *
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	2382	230	---	0	---	---
Diseases of the skin & subcutaneous tissue	951	28	---	0	---	---
Diseases of the musculoskletal system & connective tissue	2176	296	---	0	---	---
Injury & Poisoning	2136	160	---	0	---	---
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	1189	135	---	0	---	---
Number of co-morbidities						
None	1582	1532	2660	1	1.7*	1078*
One	1723	528	---	0	---	---
Two	2012	216	12100	2	6.0 (2.2, 9.8)	10087(7357, 12818)

BSI – bloodstream infection

*Numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

Table A12.5: Mean in-patient hospital costs for patients with a skin infection compared with those incurred by uninfected patients by selected characteristics

Patient characteristic	Mean hospital costs (£)				Ratio of costs (95% CI)	Additional Costs (£) (95% CI)
	No HAI		Skin			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	1439	946	3298	5	2.3 (0.8, 3.8)	1859 (276, 3441)
Female	1810	1330	3793	8	2.1 (1.1, 3.1)	1983 (774, 3193)
Age group						
18 –34	1672	485	2344	1	1.4 *	673 *
35-54	1509	627	2797	3	1.9 (0.6, 3.1)	1287 (-223, 2798)
55-74	1636	870	4031	7	2.5 (1.4, 3.5)	2394 (1309, 3479)
75+	1997	294	3942	2	2.0 (0.4, 3.5)	1945 (1810, 6075)
Specialty						
General surgery	1338	829	3570	5	2.7 (1.1, 4.2)	2232 (710, 3754)
Orthopaedics	2157	462	3565	5	1.7 (0.8, 2.5)	1407 (274, 2541)
Urology	1316	445	5919	1	4.5 *	4603 *
Gynaecology	1682	336	—	0	—	—
Obstetrics	2508	204	2621	2	1.0 (0.8, 1.3)	113 (-2033, 2259)
Admission type						
Elective	1569	1519	3354	7	2.1 (1.3, 3.0)	1784 (882, 2686)
Emergency	1828	757	3893	6	2.1 (0.4, 3.8)	2065 (634, 3495)
Discharge diagnosis group						
Infectious & parasitic diseases	867	12	—	0	—	—
Neoplasms	1714	329	4339	1	2.5 *	2626 *
Endocrine, nutritional & metabolic diseases & immunity disorders	1360	20	1152	1	0.8 *	-208 *
Diseases of blood & blood forming organs	992	3	—	0	—	—
Diseases of the nervous system & sense organs	712	2	—	0	—	—
Diseases of the circulatory system	1134	142	2352	1	2.1 *	1218 *
Diseases of the respiratory system	1726	4	—	0	—	—
Diseases of the digestive system	1249	396	7247	1	5.8 *	5999 *
Diseases of the genitourinary system	1501	519	4338	2	2.9 (0.8, 5.0)	2838 (1582, 4093)
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	2382	230	2621	2	1.1 (0.9, 1.3)	239 (-1888, 2365)
Diseases of the skin & subcutaneous tissue	951	28	953	1	1.0 *	3 *
Diseases of the musculoskletal system & connective tissue	2176	296	4128	2	1.9 0.6, 3.2)	1952 (302, 3601)
Injury & Poisoning	2136	160	4307	2	2.0 (0.7, 3.3)	2171 (201, 4141)
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	1189	135	—	0	—	—
Number of co-morbidities						
None	1582	1532	1942	4	1.2 (0.6, 1.9)	360 (-820, 1541)
One	1723	528	3282	4	1.9 (1.0, 2.8)	1559 (-114, 3233)
Two	2012	216	5187	5	2.6 (1.8, 3.3)	3175 (1458, 4892)

*Numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

Table A12.6: Mean in-patient hospital costs for patients with a single site infection at a site not classified elsewhere compared with those incurred by uninfected patients by key patient characteristics

Patient characteristic	Mean hospital costs (£)				Ratio of costs (95% CI)	Additional Costs (£) (95% CI)
	No HAI		Other site*			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	1439	946	5278	3	3.7 (1.8, 9.2)	3839 (255, 7424)
Female	1810	1330	3037	15	1.7 (0.7, 2.6)	1227 (29, 2425)
Age group						
18 –34	1672	485	6040	3	3.6 (1.0, 8.2)	4369 (2717, 6020)
35-54	1509	627	2410	5	1.6 (0.8, 2.4)	901 (-271, 2072)
55-74	1636	870	3681	7	2.2 (0.4, 4.1)	2040 (940, 3150)
75+	1997	294	1816	3	0.9 (0.2, 1.6)	-181 (78, 3554)
Specialty						
General surgery	1338	829	2474	6	1.8 (1.0, 2.7)	1136 (-250, 2522)
Orthopaedics	2157	462	5319	4	2.5 (0.1, 5.1)	3162 (1829, 4495)
Urology	1316	445	4983	3	3.8 (2.1, 9.7)	3667 92564, 4769)
Gynaecology	1682	336	1957	2	1.2 (0.8, 1.5)	276 (-728, 1279)
Obstetrics	2508	204	2136	3	0.9 (0.8, 0.9)	-373 (-2124, 1379)
Admission type						
Elective	1569	1519	2440	6	1.6 (0.9, 2.2)	871 (-101, 1843)
Emergency	1828	757	3896	12	2.1 (0.7, 3.5)	2067 (1026, 3109)
Discharge diagnosis group						
Infectious & parasitic diseases	867	12	---	0	---	---
Neoplasms	1714	329	1607	1	0. 0**	-106**
Endocrine, nutritional & metabolic diseases & immunity disorders	1360	20	1705	1	1.3 **	345**
Diseases of blood & blood forming organs	992	3	---	0	---	---
Diseases of the nervous system & sense organs	712	2	---	0	---	---
Diseases of the circulatory system	1134	142	4804	1	4.2 **	3670**
Diseases of the respiratory system	1726	4	---	0	---	---
Diseases of the digestive system	1249	396	1707	2	1.4 (1.1, 1.6)	458 (-1901, 2818)
Diseases of the genitourinary system	1501	519	1566	3	1.0 (0.5, 1.6)	65 (-955, 1085)
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	2382	230	2136	3	0.9 (0.8, 1.0)	-247 (-1983, 1489)
Diseases of the skin & subcutaneous tissue	951	28	13839	1	14.6 **	12888 **
Diseases of the musculoskletal system & connective tissue	2176	296	---	0	---	---
Injury & Poisoning	2136	160	2480	3	1.2 (0.9, 1.5)	344 (-1257, 1944)
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	1189	135	5826	3	4.9 (1.1, 10.1)	4637 (3085, 6189)
Number of co-morbidities						
None	1582	1532	3021	11	1.9 (0.5, 3.3)	1439 (706, 2171)
One	1723	528	4981	4	2.9 (0.1, 5.9)	3258 (1555, 4962)
Two	2012	216	2746	3	1.4 (0.2, 2.9)	734 (1486, 2953)

*single site infections at sites not classified elsewhere i.e. infections at a sites other than the urinary tract surgical wound, lower respiratory tract, skin, or bloodstream

*Numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

Table A12.7: Mean in-patient hospital costs for patients with more than one HAI compared with those incurred by uninfected patients by key patient characteristics

Patient characteristic	Mean hospital costs (£)				Ratio of costs (95% CI)	Additional Costs(£) (95% CI)
	No HAI		Multiple			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	1439	946	13044	4	9.1 (4.7, 13.5)	11605 (10215, 12995)
Female	1810	1330	9120	20	5.0 (2.7, 7.4)	7310 (6497, 8127)
Age group						
18 –34	1672	485	1659	1	1.0*	-12*
35-54	1509	627	12923	5	8.6 (0.0, 17.6)	11413 (9814, 13012)
55-74	1636	870	6944	11	4.2 (1.9, 6.6)	5307 (4354, 6260)
75+	1997	294	13131	7	6.6	11134
Specialty						
General surgery	1338	829	13150	11	9.8 (6.8, 12.9)	11812 (10703, 12921)
Orthopaedics	2157	462	16096	4	7.5 (0.0, 15.0)	13939 (12125, 1573)
Urology	1316	445	4842	2	3.7 (2.2, 5.1)	3526 (2341, 4724)
Gynaecology	1682	336	2265	7	1.3 (0.8, 1.8)	583 (36, 1130)
Obstetrics	2508	204	---	0	---	---
Admission type						
Elective	1569	1519	6361	14	4.1(1.4, 6.7)	4792 (4001, 5581)
Emergency	1828	757	14552	10	8.0 (4.4, 11.5)	12723 (11423, 1402)
Discharge diagnosis group						
Infectious & parasitic diseases	867	12	---	0	---	---
Neoplasms	1714	329	12051	6	7.0 (3.6, 10.4)	10338 (8982, 11693)
Endocrine, nutritional & metabolic diseases & immunity disorders	1360	20	---	0	---	---
Diseases of blood & blood forming organs	992	3	---	0	---	---
Diseases of the nervous system & sense organs	712	2	---	0	---	---
Diseases of the circulatory system	1134	142	16625	4	14.7 (9.2, 20.1)	15491 (13509, 17472)
Diseases of the respiratory system	1726	4	---	0	---	---
Diseases of the digestive system	1249	396	5174	3	4.1 (0.9, 7.4)	3926 (1978, 5873)
Diseases of the genitourinary system	1501	519	2265	7	1.5 (0.9, 2.1)	764 (91,1436)
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	2382	230	---	0	---	---
Diseases of the skin & subcutaneous tissue	951	28	---	0	---	---
Diseases of the musculoskletal system & connective tissue	2176	296	3950	1	1.8*	1774*
Injury & Poisoning	2136	160	20145	3	9.4 (0.0, 18.8)	18009 (15239, 20779)
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	1189	135	---	0	---	---
Number of co-morbidities						
None	1582	1532	8556	15	5.4 (1.9, 8.9)	6974 (4936, 9012)
One	1723	528	13268	5	7.7 (3.3, 12.1)	11546 (9913, 13178)
Two	2012	216	9971	4	5.0 (2.7, 7.2)	7958 (5971, 9946)

*Numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

The distribution of hospital costs incurred by patients with specific types of infection

A13.1 Introduction

The results of the analysis that assessed the distribution of the additional costs incurred by patients acquiring specific types of infection are presented in this appendix. The results presented in tables A13.1 – A13.7 show the distribution of the costs incurred by patients acquiring specific types of infection and how these costs compare to those incurred by uninfected patients.

Table A13.1: The distribution of hospital costs incurred by patients who acquired a urinary tract infection compared to uninfected patients

	Mean hospital costs (£)		Ratio of costs	Additional costs (£)	% contribution to additional costs
	No HAI	UTI			
	n=2276	n=88			
Hospital overheads	392.89	700.0	1.8	307.08	25.58
Directorate management	47.55	74.9	1.6	27.30	2.27
Capital charges	208.20	350.0	1.7	141.76	11.81
Medical time	150.72	242.1	1.6	91.42	7.61
Nursing care	338.11	746.7	2.2	408.60	34.03
Paramedics & specialist nurses	11.71	24.0	2.0	12.29	1.02
Physiotherapy	16.01	39.7	2.5	23.65	1.97
Consumables used for specific procedures	11.06	33.1	3.0	22.09	1.84
Surgical interventions	335.63	441.8	1.3	106.16	8.84
Antimicrobials	11.80	13.4	1.1	1.60	0.13
Non-antimicrobial drugs	32.92	46.8	1.4	13.86	1.15
Microbiology tests	5.74	15.2	2.7	9.48	0.79
Other pathology tests	54.59	104.9	1.9	50.33	4.19
Endoscopies	1.71	1.4	0.8	-0.27	-0.02
Radiology	33.35	19.1	0.6	-14.22	-1.18
Other tests	3.53	3.0	0.9	-0.51	-0.04
Total costs	1655.51	2856.1	1.7	1200.62	100.00

UTI – urinary tract infection

Table A13.2: The distribution of hospital costs incurred by patients who acquired a surgical wound infection compared to uninfected patients

	Mean hospital costs (£)		Ratio of costs	Additional costs (£)	% contribution to additional costs
	No HAI	SWI			
	n=2276	n=32			
Hospital overheads	392.89	724.87	1.84	331.98	21.74
Directorate management	47.55	91.31	1.92	43.75	2.87
Capital charges	208.20	386.17	1.85	177.96	11.65
Medical time	150.72	306.47	2.03	155.75	10.20
Nursing care	338.11	837.77	2.48	499.67	32.72
Paramedics & specialist nurses	11.71	28.41	2.43	16.70	1.09
Physiotherapy	16.01	40.46	2.53	24.45	1.60
Surgical interventions	335.63	412.12	1.23	76.50	5.01
Consumables used for specific procedures	11.06	45.85	4.15	34.80	2.28
Antimicrobials	11.80	58.82	4.99	47.02	3.08
Non-antimicrobial drugs	32.92	109.25	3.32	76.33	5.00
Microbiology tests	5.74	21.66	3.77	15.92	1.04
Other pathology tests	54.59	81.27	1.49	26.68	1.75
Endoscopies	1.71	4.09	2.40	2.38	0.16
Radiology	33.35	28.57	0.86	-4.78	-0.31
Other tests	3.53	5.40	1.53	1.87	0.12
Total costs	1655.51	3182.49	1.92	1526.98	100.00

SWI – surgical wound infection

Table A13.3: The distribution of hospital costs incurred by patients with a hospital acquired lower respiratory tract infection compared to uninfected patients

	Mean hospital costs(£)		Ratio of costs	Additional costs(£)	% contribution to additional costs
	No HAI	LRTI			
	n=2276	n=15			
Hospital overheads	392.89	754.16	1.92	361.27	13.58
Directorate management	47.55	88.09	1.85	40.54	1.52
Capital charges	208.20	398.99	1.92	190.79	7.17
Medical time	150.72	312.48	2.07	161.76	6.08
Nursing care	338.11	1563.98	4.63	1225.87	46.09
Paramedics & specialist nurses	11.71	55.63	4.75	43.92	1.65
Physiotherapy	16.01	86.31	5.39	70.31	2.64
Surgical interventions	335.63	538.20	1.60	202.57	7.62
Consumables used for specific procedures	11.06	34.67	3.14	23.61	0.89
Antimicrobials	11.80	93.90	7.96	82.10	3.09
Non-antimicrobial drugs	32.92	161.75	4.91	128.83	4.84
Microbiology tests	5.74	30.82	5.37	25.08	0.94
Other pathology tests	54.59	127.64	2.34	73.05	2.75
Endoscopies	1.71	0.00	0.00	-1.71	-0.06
Radiology	33.35	52.77	1.58	19.42	0.73
Other tests	3.53	15.69	4.44	12.16	0.46
Total costs	1655.51	4315.07	2.61	2659.56	100.00

LRTI – lower respiratory tract infection

Table A13.4: The distribution of hospital costs incurred by patients who acquired a skin infection compared to uninfected patients

	Mean hospital costs (£)		Ratio of costs	Additional costs (£)	% contribution to additional costs
	No HAI	Skin infection			
	n=2276	n=13			
Hospital overheads	392.89	893.77	2.27	500.88	25.73
Directorate management	47.55	121.90	2.56	74.35	3.82
Capital charges	208.20	497.92	2.39	289.72	14.88
Medical time	150.72	385.09	2.55	234.36	12.04
Nursing care	338.11	833.30	2.46	495.20	25.43
Paramedics & specialist nurses	11.71	39.62	3.38	27.90	1.43
Physiotherapy	16.01	59.41	3.71	43.40	2.23
Surgical interventions	335.63	478.17	1.42	142.54	7.32
Consumables used for specific procedures	11.06	105.49	9.54	94.43	4.85
Antimicrobials	11.80	50.17	4.25	38.38	1.97
Non-antimicrobial drugs	32.92	54.92	1.67	22.00	1.13
Microbiology tests	5.74	11.92	2.07	6.17	0.32
Other pathology tests	54.59	45.17	0.83	-9.42	-0.48
Endoscopies	1.71	0.00	0.00	-1.71	-0.09
Radiology	33.35	19.73	0.59	-13.63	-0.70
Other tests	3.53	5.94	1.68	2.41	0.12
Total costs	1655.51	3602.52	2.18	1947.00	100.00

Table A13.5: The distribution of hospital costs incurred by patients who acquired an infection at a site other than surgical wound, bloodstream, skin, or urinary or respiratory tract

	Mean hospital costs (£)		Ratio of costs	Additional costs	% contribution to additional costs
	No HAI	HAI at a site not classified in this study*			
	n=2276	n=18			
Hospital overheads	392.89	962.35	2.45	569.46	32.45
Directorate management	47.55	137.73	2.90	90.18	5.14
Capital charges	208.20	526.88	2.53	318.68	18.16
Medical time	150.72	397.19	2.64	246.46	14.04
Nursing care	338.11	837.59	2.48	499.49	28.46
Paramedics & specialist nurses	11.71	30.85	2.63	19.14	1.09
Physiotherapy	16.01	52.58	3.28	36.57	2.08
Surgical interventions	335.63	216.73	0.65	-118.90	-6.77
Consumables used for specific procedures	11.06	25.63	2.32	14.57	0.83
Antimicrobials	11.80	28.43	2.41	16.64	0.95
Non-antimicrobial drugs	32.92	80.55	2.45	47.63	2.71
Microbiology tests	5.74	19.46	3.39	13.71	0.78
Other pathology tests	54.59	66.50	1.22	11.91	0.68
Endoscopies	1.71	0.00	0.00	-1.71	-0.10
Radiology	33.35	24.16	0.72	-9.20	-0.52
Other tests	3.53	3.86	1.09	0.33	0.02
Total costs	1655.51	3410.48	2.06	1754.96	100.00

* single site infection at a site other than the following: urinary tract, surgical wound, skin, lower respiratory, or bloodstream

Table A13.6 The distribution of hospital costs incurred by patients who acquired a bloodstream infection compared to uninfected patients

	Mean hospital costs (£)		Ratio of costs	Additional costs (£)	% contribution to additional costs
	No HAI	BSI			
	n=2276	n=3			
Hospital overheads	392.89	411.54	1.05	18.65	0.26
Directorate management	47.55	65.85	1.38	18.30	0.25
Capital charges	208.20	223.98	1.08	15.78	0.22
Medical time	150.72	180.52	1.20	29.79	0.41
Nursing care	338.11	4715.04	13.95	4376.93	59.98
Paramedics & specialist nurses	11.71	0.00	0.00	-11.71	-0.16
Physiotherapy	16.01	83.28	5.20	67.28	0.92
Surgical interventions	335.63	849.06	2.53	513.44	7.04
Consumables used for specific procedures	11.06	785.73	71.06	774.67	10.62
Antimicrobials	11.80	120.31	10.20	108.51	1.49
Non-antimicrobial drugs	32.92	1017.26	30.90	984.34	13.49
Microbiology tests	5.74	110.14	19.18	104.40	1.43
Other pathology tests	54.59	247.40	4.53	192.81	2.64
Endoscopies	1.71	0.00	0.00	-1.71	-0.02
Radiology	33.35	130.06	3.90	96.71	1.33
Other tests	3.53	13.13	3.72	9.60	0.13
Total costs	1655.51	8953.31	5.41	7297.80	100.00

BSI – bloodstream infection

Table A13.7: The distribution of hospital costs incurred by patients who acquired more than one infection compared to uninfected patients

	Mean hospital costs (£)		Ratio of costs	Additional costs (£)	% contribution to additional costs
	No HAI	Multiple infections			
	n=2276	n=24			
Hospital overheads	392.89	1617.61	4.12	1224.72	15.09
Directorate management	47.55	188.92	3.97	141.37	1.74
Capital charges	208.20	792.85	3.81	584.65	7.20
Medical time	150.72	668.45	4.43	517.73	6.38
Nursing care	338.11	4107.03	12.15	3768.92	46.43
Paramedics & specialist nurses	11.71	216.26	18.46	204.55	2.52
Physiotherapy	16.01	147.64	9.22	131.63	1.62
Surgical interventions	335.63	486.59	1.45	150.96	1.86
Consumables used for specific procedures	11.06	270.60	24.47	259.54	3.20
Antimicrobials	11.80	141.06	11.96	129.26	1.59
Non-antimicrobial drugs	32.92	323.83	9.84	290.91	3.58
Microbiology tests	5.74	78.25	13.62	72.50	0.89
Other pathology tests	54.59	212.52	3.89	157.93	1.95
Endoscopies	1.71	7.12	4.18	5.41	0.07
Radiology	33.35	500.28	15.00	466.93	5.75
Other tests	3.53	14.72	4.17	11.18	0.14
Total costs	1655.51	9773.73	5.90	8118.22	100.00

Results of the analysis that assessed how length of hospital stay varied with site of infection and selected patient characteristics costs and site of HAI

A14.1 Introduction

The results of the analysis that assessed how length of hospital stay varied with site of infection and selected patient characteristics are presented in this appendix.

The results presented in tables A14.1-A14.7 show that whilst for all sites of infection the mean length of stay was higher in infected than uninfected patients for all the patient characteristics listed, the level of increase varied with type of infection. However, it should be noted that in some cases the number of patients in the infected groups were small and as such the results cannot be generalized.

Table A14.1 Mean length of stay for patients with a urinary tract infection and uninfected patients by key patient characteristics

Patient characteristic	Mean length of hospital stay (days)				Ratio of LOS (95% CI)	Additional days (95% CI)
	No HAI		UTI only			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	5.9	946	12.4	18	2.1(1.0, 3.2)	6.5 (3.7, 9.3)
Female	7.1	1330	11.2	70	1.6 (1.3, 1.9)	4.1 (2.3, 5.8)
Age group						
18 –34	6.0	485	8.2	15	1.4 (1.0, 1.7)	2.2 (-1.7, 6.1)
35-54	5.5	627	8.2	26	1.5 (1.3, 1.7)	2.7 (1.2, 4.3)
55-74	6.8	870	12.0	32	1.8 (1.2, 2.3)	5.2 (2.8, 7.5)
75+	9.4	294	19.2	15	2.1 (1.2, 2.9)	9.8 (4.9, 14.7)
Specialty						
General surgery	5.4	829	18.7	10	3.5 (1.8, 5.2)	13.3 (8.9, 17.7)
Orthopaedics	10.3	462	24.6	12	2.4 (1.5, 3.3)	14.3 (9.4, 19.2)
Urology	5.1	445	7.8	17	1.5 (1.1, 1.9)	2.6 (0.5, 4.8)
Gynaecology	6.1	336	8.0	36	1.3 (1.1, 1.5)	1.9 (0.6, 3.1)
Obstetrics	7.5	204	8.2	13	1.1 (0.8, 1.4)	0.8 (-2.4, 3.9)
Admission type						
Elective	6.0	1519	8.0	58	1.3 (1.2, 1.5)	2.0 (0.4, 3.5)
Emergency	7.9	757	18.2	30	2.3 (1.7, 3.0)	10.4 (7.4, 13.3)
Discharge diagnosis group						
Infectious & parasitic diseases	3.8	12	3.0	1	0.8*	-0.8*
Neoplasms	6.7	329	10.7	14	1.6 (1.0, 2.2)	4.1 (0.4, 7.7)
Endocrine, nutritional & metabolic diseases & immunity disorders	4.9	20	0.0	0	—	—
Diseases of blood & blood forming organs	4.3	3	0.0	0	—	—
Diseases of the nervous system & sense organs	3.5	2	0.0	0	—	—
Diseases of the circulatory system	5.0	142	45.0	1	9.1*	40.0*
Diseases of the respiratory system	7.0	4	0.0	0	—	—
Diseases of the digestive system	4.9	396	10.1	7	2.1 (1.3, 2.8)	5.3 (1.6, 9.0)
Diseases of the genitourinary system	5.4	519	8.0	34	1.5 (1.3, 1.7)	2.7 (1.5, 3.8)
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	7.3	230	8.0	15	1.1 (0.9, 1.3)	0.7 (-2.2, 3.7)
Diseases of the skin & subcutaneous tissue	4.5	28	0.0	0	0.0	—
Diseases of the musculoskletal system & connective tissue	10.5	296	15.0	3	1.4 (0.8, 2.0)	4.5 (-4.3, 13.3)
Injury & Poisoning	9.9	160	27.8	9	2.8 (1.6, 4.0_	17.9 (0.6, 13.9)
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	5.8	135	13.0	4	2.3 (→0.0, 5.2)	7.2 (0.6, 13.9)
Number of co-morbidities						
None	6.2	1532	9.0	56	1.5 (1.2, 1.7)	2.8 (1.3, 4.3)
One	7.0	528	12.4	24	1.8 (1.2, 2.4)	5.5 (1.9, 9.0)
Two	8.7	216	25.8	8	2.9 (1.4, 4.5)	17.0 (10.9, 23.2)

UTI – urinary tract infection; LOS – length of stay, *Numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

Table A14.2 Mean length of stay for patients with a lower respiratory tract infection patients and uninfected patients by key patient characteristics

Patient characteristic	Mean length of hospital stay (days)				Ratio of LOS (95% CI)	Additional days (95% CI)
	No HAI		LRTI only			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	5.9	946	16.8	9	2.8 (1.6, 4.1)	10.9 (7.1, 14.7)
Female	7.1	1330	11.2	6	1.6 (1.0, 2.1)	4.0 (-1.7, 9.8)
Age group						
18 –34	6.0	485	17.0	1	2.8*	11.0*
35-54	5.5	627	9.5	2	1.7 (0.3, 5.3	4.0 (-1.6, 9.6)
55-74	6.8	870	13.7	7	2.0 (1.5, 2.5)	6.9 (2.1, 11.6)
75+	9.4	294	17.2	5	1.8 (0.3, 3.4)	7.8 (-0.2, 15.9)
Specialty						
General surgery	5.4	829	15.9	10	3.0 (1.7, 4.2)	10.5 (6.1, 14.9)
Orthopaedics	10.3	462	14.0	2	1.4 (1.1, 1.6)	3.7 (-7.7, 15.2)
Urology	5.1	445	5.0	1	1.0*	-0.1*
Gynaecology	6.1	336	9.0	1	1.5*	2.9*
Obstetrics	7.5	204	17.0	1	2.3*	9.5*
Admission type						
Elective	6.0	1519	16.9	8	2.8 (1.3, 4.2)	10.9 (6.7, 15.0)
Emergency	7.9	757	11.9	7	1.5 (1.1, 1.9)	4.0 (-1.7, 9.7)
Discharge diagnosis group						
Infectious & parasitic diseases	3.8	12	0.0	0	—	—
Neoplasms	6.7	329	17.0	3	2.6 (1.4, 3.7)	10.3 (2.7, 18.0)
Endocrine, nutritional & metabolic diseases & immunity disorders	4.9	20	13.0	1	2.7*	8.2*
Diseases of blood & blood forming organs	4.3	3	0.0	0	—	—
Diseases of the nervous system & sense organs	3.5	2	0.0	0	—	—
Diseases of the circulatory system	5.0	142	0.0	0	—	—
Diseases of the respiratory system	7.0	4	15.0	1	2.1*	8.0*
Diseases of the digestive system	4.9	396	8.8	4	1.8 (1.1, 2.5)	3.9 (-1.0, 8.7)
Diseases of the genitourinary system	5.4	519	9.0	1	1.7*	3.6*
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	7.3	230	17.0	1	2.3*	9.7*
Diseases of the skin & subcutaneous tissue	4.5	28	0.0	0	—	—
Diseases of the musculoskletal system & connective tissue	10.5	296	14.0	2	1.3 (1.1, 1.6)	3.5 (-7.2, 14.2
Injury & Poisoning	9.9	160	0.0	0	—	—
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	5.8	135	25.0	2	4.3 (→0.0, 11.2)	19.2 (9.9, 28.6)
Number of co-morbidities						
None	6.2	1532	10.6	5	1.7 (1.1, 2.4)	4.4 (-0.4, 9.2)
One	7.0	528	25.7	3	3.7 (0.9, 6.4)	18.7 (8.9, 28.6)
Two	8.7	216	12.6	7	1.4 (1.0, 1.9)	3.8 (-2.3, 9.9)

LRTI – lower respiratory tract infection, LOS – length of stay, *numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

Table A14.3: Mean length of stay for patients with a surgical wound infection and uninfected patients by key patient characteristics

Patient characteristic	Mean length of hospital stay (days)				Ratio of LOS (95% CI)	Additional days (95% CI)
	No HAI		SWI only			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	5.9	946	19.33	15	3.3 (2.2, 4.4)	13.4 (10.4, 16.4)
Female	7.1	1330	10.41	17	1.5 (1.0, 1.9)	3.3 (-0.2, 6.7)
Age group						
18 –34	6.0	485	13.14	7	2.2(0.9, 3.5)	7.1 (1.4, 12.8)
35-54	5.5	627	8.25	4	1.5 90.9, 2.1)	2.7 (-1.2, 6.7)
55-74	6.8	870	14.38	16	2.1 (1.3, 2.9)	7.5 (4.3, 10.7)
75+	9.4	294	22.40	5	2.4 (1.2, 3.6)	13.0 (5.0, 21.0)
Specialty						
General surgery	5.4	829	16.67	12	3.1 (1.8, 4.4)	11.3 (7.2, 15.3)
Orthopaedics	10.3	462	16.27	11	1.6 (1.0, 2.2)	6.0 (1.0, 11.0)
Urology	5.1	445	5.00	1	1.0*	-0.1*
Gynaecology	6.1	336	5.25	4	0.9 (0.5, 1.2)	-0.9 (-4.5, 2.7)
Obstetrics	7.5	204	8.00	3	1.1 (0.6, 1.5)	0.5 (6.0, 7.1)
Admission type						
Elective	6.0	1519	12.69	16	2.1(1.5, 2.7)	6.7 (3.7, 9.6)
Emergency	7.9	757	16.50	16	2.1(1.2, 3.0)	8.6 (4.7, 12.5)
Discharge diagnosis group						
Infectious & parasitic diseases	3.8	12	0.00	0	—	—
Neoplasms	6.7	329	21.00	3	3.2 (1.9, 4.4)	14.3 (6.6, 27.0)
Endocrine, nutritional & metabolic diseases & immunity disorders	4.9	20	4.00	1	0.8*	-0.9*
Diseases of blood & blood forming organs	4.3	3	0.00	0	—	—
Diseases of the nervous system & sense organs	3.5	2	0.00	0	—	—
Diseases of the circulatory system	5.0	142	17.00	1	3.4*	12.0*
Diseases of the respiratory system	7.0	4	0.00	0	—	—
Diseases of the digestive system	4.9	396	13.75	4	2.8 (0.7, 4.9)	8.9 (3.9, 13.8)
Diseases of the genitourinary system	5.4	519	18.50	2	3.4 (→0.0, 7.6)	13.1 (8.4, 17.9)
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	7.3	230	8.00	3	1.1 (0.6, 1.6)	0.7 (-5.9, 7.3)
Diseases of the skin & subcutaneous tissue	4.5	28	8.00	1	1.8*	3.5*
Diseases of the musculoskletal system & connective tissue	10.5	296	14.00	5	1.3 (0.9, 1.7)	3.5 (-3.3, 10.3)
Injury & Poisoning	9.9	160	13.70	10	1.4 (0.6, 2.2)	3.8 (-2.2, 9.8)
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	5.8	135	26.00	2	4.5 (→0.0, 11.0)	20.2 (10.9, 29.5)
Number of co-morbidities						
None	6.2	1532	11.00	18	1.8 (1.1, 2.5)	4.8 (2.2, 7.4)
One	7.0	528	18.00	10	2.6 (1.4, 3.7)	11.0 (5.6, 16.5)
Two	8.7	216	22.25	4	2.5 (1.6, 3.5)	13.5 (5.4, 21.6)

SWI – surgical wound infection, LOS – length of stay, *numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

Table A14.4 Mean length of stay for patients with a blood stream infection and uninfected patients by key patient characteristics

Patient characteristic	Mean length of hospital stay (days)				Ratio of LOS (95% CI)	Additional days (95% CI)
	No HAI		BSI only			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	5.9	946	8.7	3	1.5 (0.8, 2.1)	2.8 (-3.7, 9.2)
Female	7.1	1330	0.0	0	---	---
Age group						
18 –34	6.0	485	12.0	1	2.0*	6.0*
35-54	5.5	627	5.0	1	0.9*	-0.5*
55-74	6.8	870	9.0	1	1.3*	2.2*
75+	9.4	294	0.0	0	---	---
Specialty						
General surgery	5.4	829	5.0	1	0.9*	-0.4*
Orthopaedics	10.3	462	12.0	1	1.2*	1.7*
Urology	5.1	445	9.0	1	1.8*	3.9*
Gynaecology	6.1	336	0.0	0	---	---
Obstetrics	7.5	204	0.0	0	---	---
Admission type						
Elective	6.0	1519	9.0	1	1.5*	3.0*
Emergency	7.9	757	8.5	2	1.1 (0.3, 2.6)	0.6 (-5.8, 10.8)
Discharge diagnosis group						
Infectious & parasitic diseases	3.8	12	0.0	0	---	---
Neoplasms	6.7	329	0.0	0	---	---
Endocrine, nutritional & metabolic diseases & immunity disorders	4.9	20	0.0	0	---	---
Diseases of blood & blood forming organs	4.3	3	0.0	0	---	---
Diseases of the nervous system & sense organs	3.5	2	0.0	0	---	---
Diseases of the circulatory system	5.0	142	0.0	0	---	---
Diseases of the respiratory system	7.0	4	12.0	1	1.7*	5.0*
Diseases of the digestive system	4.9	396	5.0	1	1.0*	0.1*
Diseases of the genitourinary system	5.4	519	9.0	1	1.7*	3.6*
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	7.3	230	0.0	0	---	---
Diseases of the skin & subcutaneous tissue	4.5	28	0.0	0	---	---
Diseases of the musculoskletal system & connective tissue	10.5	296	0.0	0	---	---
Injury & Poisoning	9.9	160	0.0	0	---	---
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	5.8	135	0.0	0	---	---
Number of co-morbidities						
None	6.2	1532	9.0	1	1.4*	2.8*
One	7.0	528	0.0	0	---	---
Two	8.7	216	8.5	2	1.0 (0.2, 1.8)	-0.2 (-11.6, 11.1)

BSI - bloodstream infection, LOS – length of stay, *numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

Table A14.5 Mean length of stay for patients with a skin infection and uninfected patients by key patient characteristics

Patient characteristic	Mean length of hospital stay (days)				Ratio of LOS (95% CI)	Additional days (95% CI)
	No HAI		Skin only			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	5.9	946	18.4	5	3.1 (1.5, 4.7)	12.5 (7.5, 17.5)
Female	7.1	1330	19.1	8	2.7 (1.4, 4.0)	12.0 (6.9, 17.0)
Age group						
18 –34	6.0	485	7.0	1	1.2*	1.0
35-54	5.5	627	11.3	3	2.1 (0.3, 3.9)	5.8 (1.2, 10.4)
55-74	6.8	870	22.0	7	3.2 (1.9, 4.5)	15.2 (10.3, 20.0)
75+	9.4	294	25.0	2	2.7 (0.6, 4.8)	15.6 (3.1, 28.2)
Specialty						
General surgery	5.4	829	17.8	5	3.3 (1.6, 5.0)	12.4 (6.2, 18.6)
Orthopaedics	10.3	462	20.4	5	2.0 (0.9, 3.0)	10.1 (2.8, 17.4)
Urology	5.1	445	38.0	1	7.4*	32.9*
Gynaecology	6.1	336	0.0	0	---	---
Obstetrics	7.5	204	8.0	2	1.1(1.2, 2.0)	0.5 (-3.4, 9.2)
Admission type						
Elective	6.0	1519	18.0	7	3.0 (1.5, 4.5)	12.0 (7.5, 16.4)
Emergency	7.9	757	19.8	6	2.5 (1.2, 3.8)	12.0 (5.7, 18.2)
Discharge diagnosis group						
Infectious & parasitic diseases	3.8	12	0.0	0	---	---
Neoplasms	6.7	329	21.0	1	3.2*	14.3*
Endocrine, nutritional & metabolic diseases & immunity disorders	4.9	20	4.0	1	0.8*	-0.9*
Diseases of blood & blood forming organs	4.3	3	0.0	0	---	---
Diseases of the nervous system & sense organs	3.5	2	0.0	0	---	---
Diseases of the circulatory system	5.0	142	15.0	1	3.0*	10.0*
Diseases of the respiratory system	7.0	4	0.0	0	---	---
Diseases of the digestive system	4.9	396	33.0	1	6.8*	28.1*
Diseases of the genitourinary system	5.4	519	27.0	2	5.0 (1.0, 9.1)	21.6 (16.9, 26.4)
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	7.3	230	8.0	2	1.1 (0.8, 1.4)	0.7 (-7.3, 8.8)
Diseases of the skin & subcutaneous tissue	4.5	28	6.0	1	1.3*	1.5*
Diseases of the musculoskletal system & connective tissue	10.5	296	24.0	2	2.3 (0.2, 4.3)	13.5 (2.7, 24.3)
Injury & Poisoning	9.9	160	24.0	2	2.4 (1.0, 3.9)	14.1 (1.2, 27.0)
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	5.8	135	0.0	0	---	---
Number of co-morbidities						
None	6.2	1532	10.0	4	1.6 (0.7, 2.6)	3.8 (-1.6, 9.2)
One	7.0	528	17.3	4	2.5 (1.0, 3.9)	10.3 (1.8, 18.8)
Two	8.7	216	27.2	5	3.1(1.8, 4.4)	18.5 (11.1, 25.8)

LOS – length of stay, *numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

Table A14.6: Mean length of stay for uninfected patients and patients with a single infection at a site other than the urinary tract, bloodstream, surgical wound, skin or lower respiratory tract by key patient characteristics

Patient characteristic	Mean length of hospital stay (days)				Ratio of LOS (95% CI)	Additional days (95% CI)
	No HAI		HAI*			
	Mean (a)	n	Mean (b)	n	(b/a)	(b-a)
Sex						
Male	5.9	946	33.7	3	5.7 (→, 14.7)	27.8 (20.9, 34.7)
Female	7.1	1330	17.2	15	2.4 (0.7, 4.1)	10.1 (6.2, 13.9)
Age group						
18 –34	6.0	485	36.3	3	6.0 (→0.0, 15.9)	30.3 (20.9, 39.7)
35-54	5.5	627	12.2	5	2.2 (0.4, 4.0)	6.7 (3.1, 10.3)
55-74	6.8	870	22.4	7	3.3 (0.6, 6.0)	15.6 (10.6, 20.6)
75+	9.4	294	10.7	3	1.1(0.0, 2.2)	1.3 (-8.9, 11.5)
Specialty						
General surgery	5.4	829	14.0	6	2.6 (1.0, 4.2)	8.6 (3.0, 14.2)
Orthopaedics	10.3	462	35.8	4	3.5 (-→0.0, 7.4)	25.5 (16.7, 34.2)
Urology	5.1	445	33.0	3	6.4 (-→0.0, 17.0)	27.9 (21.6, 34.2)
Gynaecology	6.1	336	7.5	2	1.2 (0.7, 1.7)	1.4 (-3.7, 6.4)
Obstetrics	7.5	204	6.0	3	0.8 (-→0.0, 1.7)	-1.5 (-8.0, 5.1)
Admission type						
Elective	6.0	1519	11.0	6	1.8 (0.4, 3.2)	5.0 (0.2, 9.8)
Emergency	7.9	757	24.4	12	3.1 (0.8, 5.4)	16.5 (11.6, 21.4)
Discharge diagnosis group						
Infectious & parasitic diseases	3.8	12	0.0	0	—	—
Neoplasms	6.7	329	9.0	1	1.4*	2.3*
Endocrine, nutritional & metabolic diseases & immunity disorders	4.9	20	7.0	1	1.4*	2.2*
Diseases of blood & blood forming organs	4.3	3	0.0	0	—	—
Diseases of the nervous system & sense organs	3.5	2	0.0	0	—	—
Diseases of the circulatory system	5.0	142	32.0	1	6.4*	27.0*
Diseases of the respiratory system	7.0	4	0.0	0	—	—
Diseases of the digestive system	4.9	396	7.0	2	1.4 (0.0, 2.8)	2.1 (-4.7, 9.0)
Diseases of the genitourinary system	5.4	519	6.3	3	1.2 (0.6, 1.7)	1.0 (-2.8, 4.8)
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	7.3	230	6.0	3	0.8 (->0.0, 1.7)	-1.3 (-7.9, 5.3)
Diseases of the skin & subcutaneous tissue	4.5	28	97.0	1	21.6*	92.5*
Diseases of the musculoskletal system & connective tissue	10.5	296	0.0	0	—	—
Injury & Poisoning	9.9	160	15.3	3	1.6 (0.8, 2.3)	5.4 (-5.1, 16.0)
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	5.8	135	39.0	3	6.8 (0.0, 15.3)	33.2 (23.9, 42.6)
Number of co-morbidities						
None	6.2	1532	17.1	11	2.8 (0.2, 5.3)	10.9 (7.4, 14.4)
One	7.0	528	30.8	4	4.4 (→0.0, 9.9)	23.8 (14.8, 32.7)
Two	8.7	216	16.0	3	1.8 (0.0, 3.6)	7.3 (-2.1, 16.7)

*single infection at a site other than the urinary tract, bloodstream, surgical wound, skin or lower respiratory tract

LOS – length of stay, *numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

Table A14.7: Mean length of stay for patients with more than one infection (multiple infections) and uninfected patients by key patient characteristics

Patient characteristic	Mean length of hospital stay (days)				Ratio of LOS (95% CI)	Additional days (95% CI)
	No HAI		Multiple infections			
	Mean	n	Mean	n		
	(a)		(b)		(b/a)	(b-a)
Sex						
Male	5.9	946	23.5	4	4.0 (2.8, 5.2)	17.6 (12.0, 23.2)
Female	7.1	1330	34.3	20	4.8 (2.5, 7.1)	27.1 (23.4, 30.8)
Age group						
18 –34	6.0	485	6.0	1	1.0 *	0.0*
35-54	5.5	627	29.0	5	5.3 (0.6, 10.0)	23.5 (19.4, 27.6)
55-74	6.8	870	21.3	11	3.1 (2.2, 4.0)	14.4 (10.6, 18.3)
75+	9.4	294	56.3	7	0.0 (1.9, 10.1)	46.9 (38.3, 55.5)
Specialty						
General surgery	5.4	829	48.1	11	8.9 (4.5, 13.4)	42.7 (37.8, 47.6)
Orthopaedics	10.3	462	33.5	4	3.3 (0.4, 6.1)	23.2 (14.8, 31.7)
Urology	5.1	445	25.5	2	5.0 (→0.0, 13.0)	20.4 (13.8, 27.0)
Gynaecology	6.1	336	9.3	7	1.5 (0.4, 2.6)	3.1 (0.4, 2.6)
Obstetrics	7.5	204	0.0	0	—	—
Admission type						
Elective	6.0	1519	26.2	14	4.4 (1.0, 7.7)	20.2 (16.6, 23.8)
Emergency	7.9	757	41.2	10	5.2 (3.2, 7.3)	33.3 (28.2, 38.4)
Discharge diagnosis group						
Infectious & parasitic diseases	3.8	12	0.0	0	—	—
Neoplasms	6.7	329	31.2	6	4.7 (3.7, 5.6)	24.5 (19.0, 30.0)
Endocrine, nutritional & metabolic diseases & immunity disorders	4.9	20	0.0	0	—	—
Diseases of blood & blood forming organs	4.3	3	0.0	0	—	—
Diseases of the nervous system & sense organs	3.5	2	0.0	0	—	—
Diseases of the circulatory system	5.0	142	84.5	4	17.0 (5.2, 28.8)	79.5 (66.4, 92.7)
Diseases of the respiratory system	7.0	4	0.0	0	—	—
Diseases of the digestive system	4.9	396	18.3	3	3.8 (1.6, 5.9)	13.5 (7.8, 19.1)
Diseases of the genitourinary system	5.4	519	9.3	7	1.7 (1.0, 2.5)	3.9 (1.4, 6.4)
Complications of pregnancy, childbirth & puerperium & certain conditions originating in the perinatal period	7.3	230	0.0	0	—	—
Diseases of the skin & subcutaneous tissue	4.5	28	0.0	0	—	—
Diseases of the musculoskletal system & connective tissue	10.5	296	20.0	1	1.9*	9.5*
Injury & Poisoning	9.9	160	38.0	3	3.8 (→0.0, 7.9)	28.1 (16.7, 39.5)
Symptoms, signs & ill- defined conditions; mental disorders & congenital abnormalities	5.8	135	0.0	0	—	—
Number of co-morbidities						
None	6.2	1532	21.5	15	3.5 (1.9, 5.0)	15.3 (12.3, 18.2)
One	7.0	528	49.2	5	7.1 (→0.0, 14.5)	42.2 (33.4, 51.0)
Two	8.7	216	52.8	4	6.0 (2.7, 9.4)	44.0 (35.3, 52.7)

LOS – length of stay, *numerator n=1 consequently standard deviation not estimable so confidence limits could not be estimated.

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An economic model to assess the cost and benefits of the routine use of silver alloy coated urinary catheters to reduce the risk of urinary tract infections in catheterized patients

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Summary: Prevalence studies generally find nosocomial urinary tract infections to be the most common type of nosocomial infection, accounting for between 21% and 45% of all HAIs. The main risk factor appears to be the presence of a urinary catheter, with an estimated 80% of these infections being associated with their use. This paper describes a model which quantifies the extent of the burden of these infections in terms of the number of patients affected and the costs incurred by the hospital sector; and identifies the potential benefits of the routine use of silver alloy coated catheters, as a means of reducing the incidence of this type of infection. An illustrative model of the annual costs and benefits associated with the routine use of this intervention in adult, non-day case patients admitted to the medical and surgical specialties of NHS hospitals throughout England is presented. The results suggest that a 14.6% reduction in the incidence of urinary tract infections in catheterized medical patients, and a 11.4% reduction in catheterized surgical patients, would cover the cost of the intervention. Any further reduction in incidence would result in net positive benefits.

Keywords: Nosocomial urinary tract infections; urinary catheter; modelling; costs and benefits; infection control; silver alloy coated urinary catheter.

Introduction

Studies of urinary tract infections in patients admitted to both medical and surgical specialties suggest that between 1% and 3% acquire a urinary tract infection (UTI),[1–4] whilst a study that was limited to infections occurring in surgical, urology, gynaecology and orthopaedic patients who had an operative procedure, found that 6.3% acquired a UTI.[5] Studies suggest that between 1% and 5% of patients with UTI will develop a secondary bacteraemia.[1,3,6] Prevalence studies generally find UTIs to be the most common type of nosocomial infection accounting for between 21% and 45% of all HAIs.[7–11] A key risk factor for these infections is the presence of a urinary catheter[6,12–15] with an estimated 80% of nosocomial UTIs (NUTIs) being associated with the presence of this device.[16] NUTIs result in additional morbidity[3,6,17–19] and mortality,[20,21] and represent a considerable economic burden to the health care sector, patients and their carers.[4,5,22–26] This paper presents a model which quantifies the extent of the burden in terms

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of the number of catheterized patients who acquire a UTI and the costs incurred by the hospital sector, and identifies the potential benefits of introducing the routine use of silver alloy coated catheters, to reduce them. An illustrative model of the annual costs and benefits associated with the routine use of this intervention in adult, non-day case patients admitted to the medical and surgical specialties of National Health Service (NHS) hospitals throughout England is also presented.

Aims and objectives of the economic model

The model aimed to assess the following:

(1) the number of NUTIs occurring in catheterized patients admitted to specialties of interest at one or more hospitals
(2) the economic burden these infections impose on the hospital sector in terms of the number of extra days patients remain in hospital and their associated value
(3) the potential benefits of an intervention which aims to reduce the incidence of this type of infection.

Methods

The literature on the incidence of NUTIs, risk factors for them, their impact on mortality, and the economic burden imposed was reviewed. Relevant papers were identified from the Medline database and the information obtained used to devise the model, which was subsequently developed using the spreadsheet computer package Microsoft Excel 97. The model was developed as a flexible tool, which the user could adapt to reflect the patient group of interest within a particular setting. An illustrative model of the annual costs and benefits of the routine use of silver alloy coated catheters in adult, non-day case patients, admitted to the medical and surgical specialties of NHS hospitals throughout England was subsequently constructed.

The structure of the economic model

Figure 1 illustrates the structure of the model. The starting point for this model is the number of admissions to the specialties of interest. These patients may then be sub-divided into the groups of interest, for example categorized by admission specialty. Figure 1 shows the patients subdivided into two categories however the model allows subdivision into as many sub-groups as required. The patient groups of interest are then further subdivided into those who are catheterized and those not catheterized. The number of NUTIs that might occur in these catheterized patients is then determined. Estimates of the economic impact these infections have on the hospital sector are then derived by

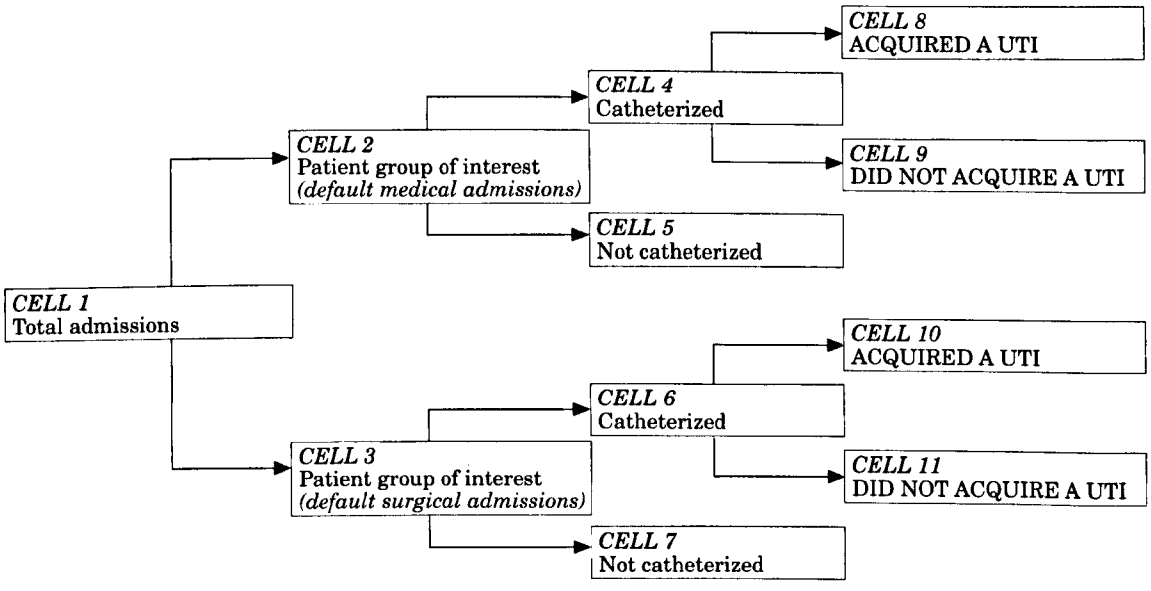

Figure 1 The structure of the economic model.

multiplying the number of NUTIs by an appropriate estimate of the number of extra days patients have to remain in hospital, and multiplying this latter figure by the relevant estimate of a cost per day in hospital. Estimates of the benefits of a specific intervention which aims to reduce the incidence of NUTIs are subsequently derived. The intervention considered in this model is the routine use of silver alloy coated urinary catheters. Estimates of the number of bed days released for alternative use and their associated value are derived.

In order to use this model the following information is required:

(1) Number of admissions to the specialties of interest at one or more hospitals.
(2) Of those patients selected, the number (or proportion) of patients within the group of interest, for example, the number of patients admitted to relevant specialties. In Figure 1 the patients have been subdivided into medical admissions and surgical admissions.
(3) The number (or proportion) of patients in the selected groups of interest who are catheterized.
(4) The number or estimated incidence of NUTIs occurring in these catheterized patients.
(5) The average number of additional days that catheterized patients with a NUTI remain in hospital.
(6) The cost of an additional day in hospital.
(7) The cost and estimated effectiveness of the intervention.

A facility, which enabled sensitivity analysis to be conducted, was also built into the model. Sensitivity analysis reveals how the varying of one or more assumptions affects the model. In this model the sensitivity analysis was used to assess the effect of changing the estimates of the incidence of NUTIs in catheterised patients, the effectiveness of the intervention, the number of extra days patients remained in hospital as a result of the infection, and the cost per additional bed day.

The model produces four main outputs:

(1) The number of catheter related NUTIs that would occur in a pre-defined patient group.
(2) The additional bed days utilized as a result of a NUTI.
(3) The value of the resources used by catheterized patients who acquire a NUTI.
(4) The net financial benefits associated with the routine use of silver alloy coated catheters.

Results of the illustrative model

A model to assess the costs associated with catheter-associated NUTIs occurring in adult (≥18 years of age), non-day case admissions to the medical and surgical specialties of NHS hospitals throughout England (Figure 2), and the potential benefits of

Results	No. of bed days	Cost (£)
Medical patients – NUTI	62 553	14 574 787
Surgical patients – NUTI	175 621	52 510 702

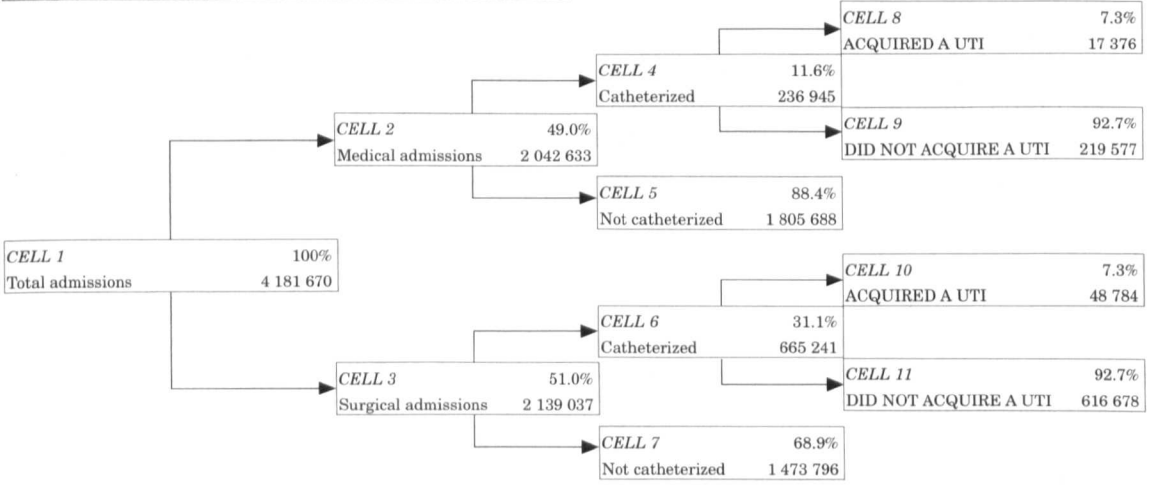

Figure 2 The economic model of the costs of catheter associated NUTIs occurring in adult, non-day case patients admitted to the medical and surgical specialties of NHS hospitals throughout England.

Table I *The estimated costs and benefits of the routine use of silver alloy coated catheters in adult patients, excluding day cases, admitted to the medical and surgical specialties of NHS hospitals throughout England at different levels of effectiveness*

		Effectiveness of catheter at preventing NUTIs										
Surgical patients		1%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Bed days made available		1756	17562	35124	52686	70248	87811	105373	122935	140497	158059	175621
Gross benefits (value of bed days)	(£ Million)	0.53	5.25	10.50	15.75	21.00	26.26	31.51	36.76	42.01	47.26	52.51
Additional cost of silver alloy coated catheter	(£ Million)	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99
Net benefits	(£ Million)	−5.46	−0.74	4.51	9.77	15.02	20.27	25.52	30.77	36.02	41.27	46.52
		Effectiveness of catheter at preventing NUTIs										
Medical patients		1%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Bed days made available		626	6255	12511	18766	25021	31276	37532	43787	50042	56297	62553
Gross benefits (value of bed days)	(£ Million)	0.15	1.46	2.91	4.37	5.83	7.29	8.74	10.20	11.66	13.12	14.57
Additional cost of silver alloy coated catheter	(£ Million)	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13
Net benefits	(£ Million)	−1.99	−0.68	0.78	2.24	3.70	5.15	6.61	8.07	9.53	10.98	12.44

introducing the routine use of silver alloy coated urinary catheters (Table I) was developed. This model uses real data obtained from a variety of sources, details of which are given below together with the output of the model.

Number of admissions (cell 1)

The number of adult (⩾18 years of age), non-day case admissions to the medical and surgical specialties of all NHS hospitals throughout England was obtained from the hospital episodes statistics database.[27] In 1994/5 there were 4181670 admissions that met this criterion. Appendix 1 provides details of the specialties included in the illustrative model.

Number of patients who were medical and surgical admissions (cell 2 and 3)

The number of patients admitted to medical and to surgical specialties was also obtained from the hospital episodes statistics database.[27] In 1994/5 2042633 (49%) of the 4181670 adult, non-day case admissions to the medical and surgical specialties of NHS hospital in England were surgical admissions and 2139037 (51%) were medical admissions. Appendix 1 contains details of the specialties included in these two categories.

Number of patients who are catheterized (cells 4 and 6)

Information on catheterization rates is not routinely collected and as such the model utilizes estimates taken from the literature. For the purposes of this illustrative model estimates taken from the results of an audit of infection control policies and practices in 19 hospitals in England and Wales have been applied.[28] The audit study provided information on the proportion of medical, surgical, orthopaedic, and gynaecology patients who were catheterized at some point during their in-patient stay. The study was restricted to adult patients who had a minimum hospital stay of three days. The median values for the 19 sites for each speciality were as follows: medical 11.6% (range: 5.0–17.0%); general surgery 34.4% (range: 16.2–50.0%); orthopaedic 17.3% (range: 10.1–26.0%) and gynaecology 40.4% (range: 20.9–72.0%). This model utilizes the median value for the medical specialties (11.6%: range 5.0–17.0%) and a weighted

value for all surgical specialties (31.1%: range 16–49%). This latter estimate was derived from the individual surgical speciality estimates and data on the number of admissions to these specialties. Although the case-mix of patients studied in this earlier study is not directly comparable with the patient group described in this model, and therefore it is not clear how accurately these estimates reflect the actual catheterization rate in the selected patient group, it was felt that these were the best estimates currently available.

Number (or percentage) of catheterized patients who acquire a NUTI (cells 8 and 10)

Data on the incidence of NUTIs in catheterized patients were not available. In their absence, estimates were derived as follows. A study of the incidence of hospital acquired infections occurring in 3326 adult patients admitted to the general surgical, general medical, orthopaedic and gynaecology specialties of a district general hospital, indicated that 83 (2.5%) acquired a UTI.[2] Data from the US suggests that 80% of NUTIs occur in catheterized patients.[16] If this assumption is applied to the number of NUTIs observed it follows that 66.4 of the 83 NUTIs observed occurred in catheterized patients.

In order to obtain an estimate of the incidence of NUTIs in catheterized patients, this figure was expressed as a percentage of the number of catheterized patients. In the absence of information on how many of the 3326 patients involved in the incidence study[2] were catheterized, an estimate was derived by applying the specialty – specific median catheterization rates observed in the audit of infection control at 19 hospitals in England and Wales[28] to data on the number of patients within each specialty, and the number of catheterized patients was summed. Overall an estimated 905.47 of the 3326 patients involved in the incidence study[2] were catheterized at some stage during their admission. If the estimated number of catheter-related NUTIs (66.4 NUTIs) is expressed as a percentage of these 905.47 catheterized patients, then the incidence of NUTIs in catheterized patients is estimated as 7.3%, (66.4/905.47) and this figure was used in this model.

The number of additional days that catheterized patients with a NUTI remain in hospital

The assumption was made that NUTIs occurring in surgical patients, on average, result in patients remaining in hospital an additional 3.6 days. This estimate was taken from the results of a study which estimated the cost of NUTIs occurring in adult patients admitted to the gynaecology, orthopaedic, general surgery and urology specialties of a district general hospital.[5] In the absence of any literature that exclusively considered the impact of NUTIs in medical patients on hospital sector resources use, the same estimate was applied to NUTIs occurring in medical patients.

The cost of an additional days stay in hospital

Estimates of the cost per bed day were derived as follows. Data were retrieved from the Chartered Institute of Public Finance Accountants' Health Service Database[29] on total bed days supplied, by speciality, for as many hospitals as provided data. Corresponding data were also extracted on expenditure for these bed days. These specialties were organised into medical and surgical specialties and the average cost of providing a bed day was derived for each speciality. To provide an overall figure for surgical and medical specialities, the sum of the expenditures was divided by the sum of the bed days (Table II).

Table II *Average value of a bed day by speciality*

Medical/surgical category	Specialties	Mean (£)
Surgical specialties	General surgery	266
	Urology	263
	Orthopaedics	264
	Gynaecology	323
	Neuro surgery	410
	Plastic surgery	358
	Cardiothoracic	522
	All surgical specialities	299
Medical specialties	Geriatrics	125
	Cardiology	386
	Infectious diseases	275
	Medical oncology	327
	Neurology	258
	Rheumatology	248
	Gastroentorology	241
	Haematology	299
	Thoracic medicine	244
	GU medicine	295
	Nephrology	276
	Rehabilitation	188
	General medicine	171
	All medical specialties	233

Data source: Chartered Institute of Public Finance Accounts' Health Service Database, London (1998).

Estimating the potential benefits of the routine use of silver alloy coated catheters

Having identified the number of patients who acquire a NUTI, and the estimated impact these infections have on hospital sector resource use, the final stage of this model is to identify the potential savings that might result from the routine use of silver alloy coated catheters. In order to estimate these benefits information on the cost of the intervention and its estimated level of effectiveness is required. The estimated additional cost of silver alloy coated catheters compared to non-coated catheters is £9.[30] If this figure is applied to all catheterized patients it follows that the routine use of this type of catheter in medical patients would cost an estimated £2 132 509 and in surgical patients £5 987 165. Estimates of the effectiveness of the intervention may be obtained from the results of clinical trials.[31–34] However, it should be noted that while these trials demonstrate that the intervention is effective at reducing the incidence of NUTIs, the impact that their routine use has on the incidence of NUTIs in other settings will depend on the infection rate and the case-mix of patients involved, and as such a range of estimates of the effectiveness of this intervention, (0–100%) has been incorporated into this model.

Results of the illustrative model

If the above assumptions are accepted, the model suggests that 17 376 medical and 48 784 surgical patients acquire a catheter related NUTI (Figure 2). Medical patients were estimated to remain in hospital for an additional 62 553 days, valued at £15 million, and surgical patients were estimated to remain in hospital for additional 175 621 bed days, valued at £53 million.

The additional cost of the routine use of silver alloy coated catheters was balanced against these costs assuming different levels of effectiveness at preventing NUTIs (Table I). If the routine use of silver alloy coated catheters was adopted at an additional cost of £9 per catheter then in order for the benefits to outweigh the costs 14.6% of infections occurring in medical patients need to be prevented (Figure 3) and 11.4% of infections occurring in surgical patients need to be prevented (Figure 4). The results of some clinical trials suggest that the proportion of infections that could be prevented may be higher than this.[31–34] For example, one study found that the routine use of silver alloy coated catheters reduced the risk of infection by 32%.[34] Clearly at this level of effectiveness the benefits of the use of silver alloy coated catheters significantly outweigh the costs.

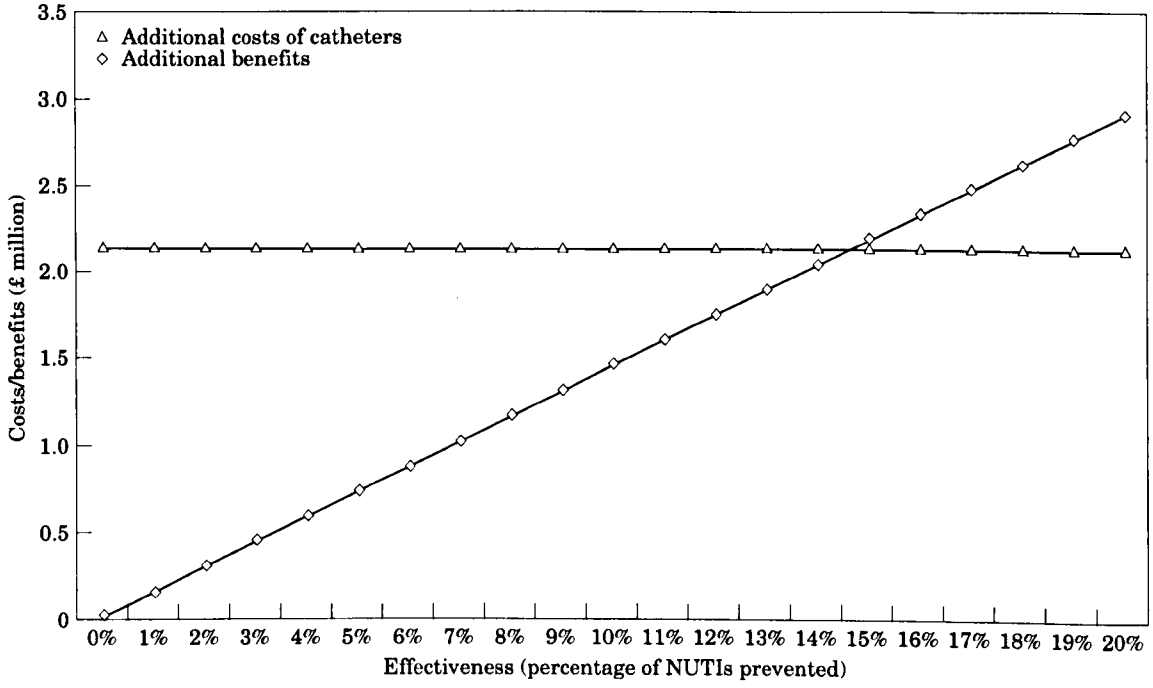

Figure 3 Costs and benefits of the routine use of silver alloy coated catheters in adult, non-day case patients admitted to the medical specialities of NHS hospitals throughout England at different levels of effectiveness.

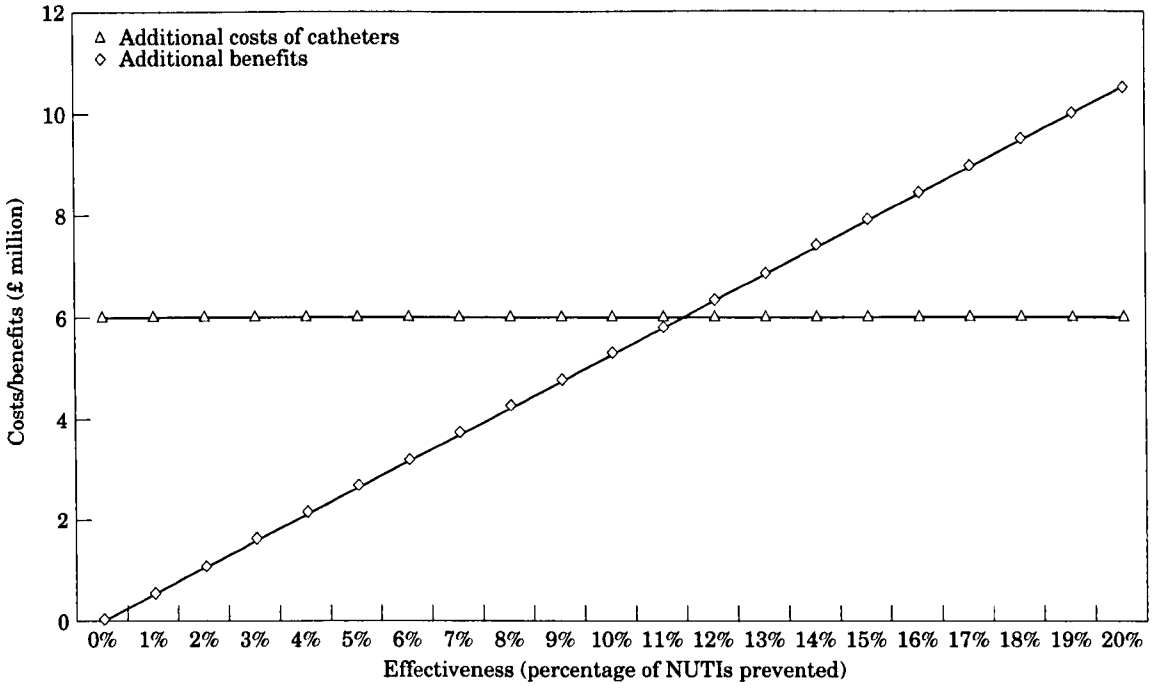

Figure 4 Costs and benefits of the routine use of silver alloy coated catheters in adult non-day case patients admitted to the surgical specialties of NHS hospitals throughout England at different levels of effectiveness.

Table III *The percentage of infections that need to be prevented if the benefits of the routine use of silver alloy coated urinary catheters are to cover the cost of the intervention and how this varies when the model parameters are changed*

Parameter changed	Percentage of infections that need to be prevented if the benefits of the intervention are to cover the cost of the intervention		
		Medical specialties (%)	Surgical specialties (%)
Incidence of NUTIs in catheterized patients	4.0%	26.82	20.90
	5.0%	21.46	16.72
	5.0%	21.46	16.72
	6.0%	17.88	13.94
	7.0%	15.33	11.94
	7.3%*	**14.63**	**11.40**
	8.0%	13.41	10.45
	9.0%	11.92	9.29
	10.0%	10.73	8.36
Average number of extra days patients remain in hospital	2	26.34	20.52
	3	17.56	13.68
	3.6*	**14.63**	**11.40**
	4	13.17	10.26
	5	10.53	8.21
	6	8.78	6.84
Cost per bed day	50% of cost used	29.26	22.80
	100% of cost used*	**14.63**	**11.40**
	150% of cost used	9.75	7.60

*** estimates used in the illustrative model.**

Sensitivity analysis

Table III shows the results of the sensitivity analysis, which assessed the impact that varying the key assumptions used in the model had on its results. The impact of varying the incidence of NUTIs in catheterized patients, the number of additional bed days that patients remained in hospital, and the value of extra bed days were assessed.

As the values of individual parameters are decreased the intervention needs to be more effective for the benefits to cover the costs and vice versa. For example, if the incidence of NUTI in catheterized patients is only 4% rather than 7.3% as assumed in the model, then providing all the other assumptions are valid, 20.9% of NUTIs occurring in catheterized surgical patients, and 26.8% in medical patients would need to be prevented if the costs of the intervention are to be covered. However, if the incidence of NUTI is higher, then providing the other assumptions are accepted, a lower percentage of infections would need to be prevented to cover the cost of the intervention. For example, if the incidence of NUTIs in catheterized medical and surgical patients was 10%, an 8.4% reduction in the incidence of NUTIs in catheterized surgical patients would be needed to cover the cost of the intervention, and a 10.7% reduction in medical patients.

The effects of altering more than one parameter at a time were not explored in this model. Nor was the effect of varying the proportion of patients who are catheterized. Changing the proportion of patients catheterized will inevitably alter the number acquiring an infection, the number of extra days utilised by infected patients and the cost of this prolonged hospital stay, but will not affect the proportion of infections that needs to be prevented to cover the cost of the intervention.

Discussion

Validity of the model

The validity of the model is dependent on how realistic the structure of the model is and how accurately the estimates of the parameters used reflect what is happening in the patient group of interest. The illustrative model presented in this paper was based on information derived from the literature and a number of assumptions. However, the model has been developed so that at the level of the individual hospital, more accurate estimates, which reflect the patient group of interest in a particular setting, may be used. For example, the user may have access to local information on the number, or proportion of patients catheterized, the incidence of NUTIs in catheterized patients, and the number and cost of the extra days infected patients remain in hospital. Alternatively, the estimates used in the illustrative model may be replaced by those taken from other studies, where case mix more closely reflects the patient group of interest. Equally, the user may consider the routine use of the more expensive silver alloy coated catheter to be inappropriate and wish to limit it to patients considered to be at high risk of acquiring a urinary tract infection. The user would simply need to substitute data on the number of admissions, with data on the number of patients in the high-risk category, and replace the incidence figures with estimates which reflect the incidence of NUTIs in the high risk group.

Interpreting the results of the model

While a number of studies suggest that the use of silver alloy coated catheters is an effective means of reducing the incidence of NUTIs,[31–34] it should be noted that the validity of some of the estimates has been questioned,[35] and a study by Thiobon *et al.*[36] failed to identify any significant preventative effect. Concerns relate to factors such as the small number of patients involved in some of the studies, and effectiveness being assessed in terms of ability to prevent bacteriuria rather than symptomatic NUTIs.[35,36] However, more recently a relatively large study[34] assessed how effective these catheters were at reducing NUTIs as defined by Centre for Disease Control and Prevention criteria.[37] The results of this latter study confirmed those of earlier studies that demonstrated that silver alloy catheters exerted a preventative effect. The use of silver alloy coated catheters was found to reduce the risk of acquiring an infection by 32%.[34] While it may not be possible to achieve similar levels of reduction in the incidence of this type of infection in all settings, the level of effectiveness achieved to some extent depending on the scope for reducing the incidence of NUTIs, the results of this model suggest that the additional costs associated with the routine use of silver alloy coated catheters can be recouped at relatively low levels of effectiveness and any further reductions result in net benefits.

The results of the sensitivity analysis demonstrate that even when a relatively conservative

estimates of the incidence of NUTIs, or the number and value of extra days patients remain in hospital are applied, the benefits of the routine use of silver alloy coated catheters continue to outweigh the additional expenditure. However, it should be noted that the sensitivity analysis did not consider the impact of varying more than one parameter at a time.

The model did not assess the benefits associated with a reduction in secondary bacteraemias and as such the benefits of preventing NUTIs may have been underestimated in the illustrative model. An estimated 1–5% of patients with catheter associated bacteriuria will develop a bacteraemia[1,3] which may further prolong the length of hospital stay and represent an additional burden to the health sector. If the use of silver alloy coated catheters is effective in preventing NUTIs in patients, who in the absence of this intervention would have acquired both a NUTI and a bacteraemia, the benefits of preventing NUTIs through the routine use of this intervention will increase.

It should be understood that the cost of an infection, if avoided, will not all be realised as a cash saving. Many of the costs/benefits are fixed and it is principally the variable costs/benefits (for example drugs, and other consumable items), which represent a smaller proportion of the total costs, that would show as cash savings and as such expenditure that could be avoided.

While the fixed costs avoided will not all be realised as cash savings, they do represent economic benefits as these costs could be deployed to produce other outputs other than treating infection. It is therefore justified to use the full cost data (fixed and variable costs) to represent the benefits. These methodological issues are discussed in more detail elsewhere.[26]

Potential applications

The model described in this paper can be adapted to the particular needs of the user. It may be of particular interest to infection control workers who wish to demonstrate the magnitude of the burden of this type of infection and the benefits associated with the routine use of silver alloy coated catheters. The information derived from the model may be used to justify the additional expenditure associated with this intervention, and to change policy regarding infection control practice.

While the model presented in this paper focuses on NUTIs occurring in catheterized patients and the routine use of silver alloy coated catheters as a means of reducing this type of infection, the model could also be adapted to assess the benefits of an alternative intervention and/or the prevention of infections at other sites.

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Appendix I *Number of adult non-day case admissions to selected specialties of NHS hospitals throughout England in 1994/5*

	Speciality	Number of adult (≥18), (non-day case admissions)
Medical specialties	General medicine	1 090 716
	Gastroentorology	17 839
	Endocrinology	5038
	Haematology (clinical)	46 626
	Clinical pharmacology	5 578
	Rehabilitation	3 706
	Palliative medicine	4 772
	Cardiology	96 488
	Dermatology	13 739
	Thoracic medicine	42 485
	Infectious diseases	12 206
	Genito-urinary medicine	1 985
	Nephrology	43 531
	Medical oncology	37 572
	Nuclear medicine	151
	Neurology	43 316
	Clinical neuro-physiology	307
	Rheumatology	38 165
	Geriatric medicine	431 310
	Old age psychiatry	38 620
	Radiotherapy	56 325
	Radiology	1 575
	General pathology	8
	Blood transfusion	54
	Chemical pathology	495
	Haematology	9 970
	Histopathology	2
	Immunopathology	53
	Medical microbiology	1
Surgical specialties	General surgery	804 676
	Urology	223 685
	Trauma & orthopaedics	464 948
	Neurosurgery	37 587
	Plastic surgery	59 060
	Cardiothoracic surgery	47 686
	Gynaecology	501 395

Data source: Hospital Statistics Database 1994/5.

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The rate and cost of hospital-acquired infections occurring in patients admitted to selected specialties of a district general hospital in England and the national burden imposed

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Summary: Between April 1994 and May 1995 4000 adult patients admitted to selected specialties of a district general hospital were recruited to this study. Hospital-acquired infections presenting during the in-patient stay were identified using previously validated methods of surveillance, and information on daily resource use by both infected and uninfected patients was recorded and estimates of their cost derived. Linear regression modelling techniques were used to estimate how much of the observed variation in resource use and costs could be explained by the presence of an infection. Complete in-patient data sets were obtained for 3980 patients. Of these, 309 patients (7.8%; 95% CI; 7.0, 8.6) presented with one or more hospital-acquired infections during the in-patient period. Infected patients, on average, incurred hospital costs 2.9 (regression model estimate: 2.8; 95% CI; 2.6, 3.0) times higher than uninfected patients, equivalent to an additional £3154 (regression model estimate £2917). Both the incidence and the economic impact varied with site of infection and with admission specialty. Estimates of the burden of hospital-acquired infections occurring in adult patients admitted to similar specialties at NHS hospitals in England were derived from the results of this study. An estimated 320 994 (95% CI; 288 071, 353 916) patients per annum acquire one or more infections which present during the in-patient period, and these infections cost the hospital sector an estimated £930.62 million (95% CI; £780.26; £1080.97 million) per annum. The results presented represent the gross economic benefits that might accrue if these infections are prevented. Further research is required to establish the net benefits of prevention.

Keywords: Hospital-acquired infection; incidence; economic burden.

Introduction

At any one time approximately 10% of hospitalized patients have an infection acquired after admission to hospital.[1] These infections result in additional costs to the healthcare sector, patients and those who care for them.[2] Few studies have estimated the incidence of these infections occurring in a wide range of patients.[3,4] While a number of studies have assessed the economic burden imposed by these

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infections, the estimates derived have generally been limited to the costs incurred by the hospital sector, and little information on the distribution of the additional costs incurred between the budgetary centres of the hospital has been provided.[5–7] This study provides a more comprehensive assessment of the incidence of these infections and their impact on resource use. The results of the analysis examining the incidence of hospital-acquired infection presenting during the in-patient period and their impact on hospital sector resource use and costs are presented in this paper.

Methods

Study site

Patients were recruited from a district general hospital within close proximity of the two institutions involved in the research. This type of hospital was selected in preference to tertiary referral centres in order to facilitate the generalizability of the study results to other healthcare settings. The hospital selected was part of an English NHS Trust providing general acute services, selected regional tertiary specialist services and primary care services. At the time of recruitment it had 579 beds.

A retrospective assessment of how representative the study hospital was of others in England was undertaken in terms of the number of bed days produced, number of staff employed, the average cost per bed day, the average length of stay and the expected length of stay given the case mix of patients. Data on the number of bed days produced, number of staff employed and average cost per bed day at the study hospital and for hospitals throughout England were retrieved from the Chartered Institute of Public Finance Accountants/Healthcare Financial Managers database.[8] The study hospital values for these three variables were found to lie within the interquartile range of the distributions. The Health Services Indicators database[9] provided information on the average length of stay, and expected length of stay given the case mix of patients for some of the specialties involved in this study, at both the study site and at other hospitals throughout England. The study hospital values for these variables fell within the interquartile range of the distributions. These findings suggest that for the variables considered, the study hospital was not atypical of other hospitals throughout England.

At the time the study was undertaken the study hospital's infection control team consisted of two infection control nurses and a microbiologist who dedicated approximately 3 h to infection control team activities per week. This infection control team was responsible for infection control at the study hospital and 60 non-acute beds at two other hospitals, equivalent to one ICN per 289 acute beds and 30 non-acute beds. This ratio of infection control nurses to number of beds is higher than the national average of one ICN to 535 beds.[10]

Patients

Adult (≥18 years of age) medical; surgical; orthopaedic; urology; gynaecology; ear, nose and throat; elderly care; and, if they had had a Caesarean section, obstetric patients admitted to selected wards at the study hospital who had a minimum in-patient stay of 30 h were eligible for recruitment. Day case patients and patients who remained in hospital overnight and were discharged early the following day were therefore omitted from this study. Resource constraints prohibited the inclusion of these patients.

Recruitment

Having obtained ethical committee approval, recruitment began in April 1994 and continued until May 1995. The informed written consent of eligible patients was obtained by one of six research assistants, all of whom were experienced registered nurses and trained in recruitment, surveillance and data collection methods.

From the outset it was clear that the research assistants would not be able to invite all eligible patients to participate in this study. While recruitment itself did not take up a lot of the available time, the identification of hospital-acquired infections (HAIs) and the collection of detailed data on resource use was time consuming. The research assistants were instructed to give priority to the collection of complete data sets rather than recruiting all eligible patients and were given appropriate training and supervision to minimize any selection bias.

Information on the reason eligible patients were not recruited (e.g., the patient declined participation, or was not recruited due to practical reasons such as insufficient time) and the age, sex, admission type and admission specialty was recorded. These data were subsequently analysed to check for any recruitment bias.

Data collection

Baseline information including age, sex, diagnosis, co-morbidities and social circumstances was obtained from the patients themselves and their medical and nursing records.

Hospital-acquired infections were identified using the reference method of surveillance and previously validated definitions of infections.[11] The reference method of surveillance aims to identify all HAIs presenting during the in-patient period. It involves consulting relevant healthcare records on a regular basis to obtain evidence of the presence of one or more infections. If this evidence meets the criteria detailed in the definitions used, an HAI is recorded as being present. The site of the infection, date of onset, and, if known, the causative pathogen are also recorded.

Data on daily resource use, including contacts with professionals allied to medicine, laboratory radiological and other diagnostic tests undertaken, surgical and medical procedures performed, drugs prescribed, and care administered by nursing staff were obtained from the patients' medical, nursing, laboratory and paramedic records.

Development of monetary valuations of resource use

Estimates of the value of the hospital resources used by individual patients were made and the methods used are reported in detail elsewhere.[12] The methods were designed to identify the likely opportunity costs of the resources used.

The hospital costs incurred by patients recruited into this study were categorized as either costs associated with occupying a hospital bed or the cost of specific care and treatment administered to individual patients.

The cost of occupying a hospital bed included the cost of hospital overheads, directorate management and capital charges. The methods used to attribute these costs were developed from interviews with the relevant managers and health care professionals. A cost per bed day was derived for each clinical specialty and this estimate multiplied by the patient's length of hospital stay.

Costs associated with care and treatment administered included the cost of medical time, nursing time, the time of other health care professionals such as physiotherapists, and the cost of diagnostic investigations, procedures carried out and consumables used. Estimates of the daily cost of medical care were derived for each specialty and this was allocated according to the patient's length of hospital stay. Nursing costs were allocated to patients based on the amount of nursing care patients received each day and unit costs were derived for contacts with professionals allied to medicine and allocated in accordance with the number of contacts supplied. Unit costs were also derived for laboratory investigations, radiological investigations, electrocardiograms, endoscopic procedures, surgical procedures, pharmaceuticals, dressings and other consumable products supplied to the patient. These costs were allocated in accordance with the individual patient's consumption of these resources.

All data on the cost of resources were retrieved from the finance department of the hospital and the clinical specialties themselves.

Data analysis

Checking for recruitment/selection bias

The age, sex, admission type and admission specialty distributions of patients recruited into the study were compared to the distributions that would have been present if all eligible patients were recruited.

Incidence of hospital-acquired infections presenting during the in-patient period

The number of patients with one or more HAIs presenting during the in-patient period was expressed as a percentage of the number of patients discharged and 95% confidence intervals derived. Site and specialty specific estimates were also derived.

Attribution of costs to HAI

Factors other than infection may have an impact on resource use.[2] Linear regression modelling techniques were used to control for a range of factors that could potentially influence the level of resource use: age, sex, diagnosis, number of co-morbidities, admission specialty and admission type. Since the cost and length of hospital stay distributions included a few very high values they were skewed to the right. For this reason the analysis was performed assuming that the underlying distribution was Gamma in form (this distribution, very similar to the log-Normal, is appropriate for skewed data[13]). Estimates of the impact of one or

more HAIs, and of specific types of infection on resource use, adjusted for the effects of confounding variables were thus obtained from the simplest regression model that adequately represented the variation in the costs incurred by infected compared with uninfected patients.

Deriving national estimates of the number of patients who acquire one or more HAIs

National estimates of the number of adult patients who acquired one or more infections in hospital, which presented during the in-patient stay, were derived by applying the observed in-patient incidence rate and 95% confidence interval to data on the number of adult patients (aged ≥ 18), excluding day cases, admitted to similar specialties, in NHS provider units throughout England in 1994/5 (Table I). The same approach was used to derive specialty specific estimates of the number of patients acquiring one or more infections and estimates of the number of patients acquiring specific types of infection.

Deriving national estimates of the cost of HAIs to the hospital sector

Estimates of the burden these infections imposed on the hospital sector were derived from data on the observed incidence of hospital-acquired infections presenting during the in-patient period (Tables II, III); the estimated ratio of the hospital costs incurred by infected compared to uninfected patients obtained from the linear modelling analysis (Tables II, III); the mean hospital costs incurred by uninfected patients (Tables II, III) and data on the number of adult admissions (Table I). If N is the number of patients admitted nationally, C the baseline cost of treating uninfected patients, i the estimated incidence and r the estimated ratio of costs incurred by infected compared to uninfected patients, then $NiC(r-1)$ provides an estimate of the national burden.

The variance of this estimate was derived from the standard deviations of the estimates of the incidence and ratio of costs, sd$i$ and sd$r$ respectively, as follows: $N^2C^2[i^2\mathrm{sd}r^2+(r-1)^2\,\mathrm{sd}i^2]$.

This estimated variance was subsequently used to obtain 95% confidence intervals for the estimates of the national burden of infection, it being assumed that the sampling error in such an estimate would be approximately normal. Estimates of the number of additional days patients remained in hospital and site and specialty specific estimates of the burden imposed were made using the same approach.

Table I *The number of adult, non-day case, admissions to selected specialties of NHS Hospitals in England in 1994/5*

Specialty	Number of adult admissions, excluding day cases, in 1994/5*
Gynaecology	501 395
Elderly care	431 310
Obstetrics (caesarean sections only)	84 089
Orthopaedics	464 948
Surgery	804 676
Urology	223 685
Medicine	1 431 984
Ear, nose and throat	173 216
All specialties	4 115 303

Source: Hospital episodes statics data set 1994/5.[14]
* Number of adult patients, excluding day cases, admitted to the specialties listed in Appendix I at NHS provider units in England in 1994/5.

Results

Sample characteristics

Between April 1994 and May 1995, 5909 patients were eligible for recruitment. Of these, 4000 (67.7%) were recruited, 343 (5.8%) declined participation, 1553 (26.3%) were not recruited due to insufficient time, and in a further 13 cases (0.2%) information on the reason for non-recruitment was not recorded. The age, sex, admission type and admission specialty of patients recruited into the study was broadly similar to that which would have been present if all eligible patients had been recruited (Table IV).

Incidence of HAIs

During the in-patient period, 309 (7.8%; 95% CI; 7.0, 8.6) patients presented with one or more HAIs. Site specific estimates indicated that urinary tract infections had the highest incidence, followed by multiple infections (Table II). Specialty specific estimates indicated that the incidence varied considerably with specialty, being lowest amongst ear, nose and throat patients and highest in gynaecology, elderly care and obstetric patients (Table III).

Table II *The incidence of HAI by site of infection and its impact on the length and cost of hospital stay*

Site of HAI	Incidence		Cost (£)			Length of stay (days)		
	N	IR% (95% CI)	Mean costs	Ratio of costs* (model estimate: 95% CI)‡	Additional cost† (model estimate)‡	Means LoS	Ratio of days* (model estimate: 95% CI)‡	Additional days† (model estimate)‡
No HAI	3671		1628			7.6		
Urinary tract	107	2.7 (2.2 to 3.2)	2955	1.8 (1.7:1.5 to 1.9)	1327 (1122)	13.7	1.8 (1.7: 1.5 to 1.9)	6.1 (5.1)
Multiple	57	1.4 (1.1 to 1.9)	10780	6.6 (6.3: 5.4 to 7.4)	9152 (8631)	45.4	6.0 (4.8:4.0 to 5.8)	37.8 (29.1)
Lower respiratory tract	48	1.2 (0.9 to 1.6)	4027	2.5 (2.3: 1.9 to 2.7)	2398 (2080)	20.1	2.6 (2.1: 1.7 to 2.6)	12.5 (8.4)
Surgical wound	38	1.0 (0.7 to 1.3)	3246	2.0 (2.0: 1.6 to 2.4)	1618 (1594)	14.1	1.9 (1.9:1.6 to 2.4)	6.5 (7.1)
Other	30	0.8 (0.5 to 1.1)	3892	2.4 (2.5: 2.0 to 3.1)	2263 (2465)	21.0	2.8 (2.6:2.1 to 3.4)	13.4 (12.4)
Skin	25	0.6 (0.4 to 0.9)	3418	2.1 (2.0: 1.6 to 2.5)	1790 (1615)	19.6	2.6 (2.4:1.8 to 3.1)	12.0 (10.6)
Bloodstream	4	0.1 (0.0 to 0.3)	7026	4.3 (4:8:2.6 to 8.8)	5397 (6209)	9.5	1.2 (1.5:0.8 to 3.0)	1.9 (4.0)
Any site	309	7.8 (7.0 to 8.6)	4782	2.9 (2.8:2.6 to 3.0)	3154 (2917)	21.7	2.9 (2.5:2.3 to 2.7)	14.1 (11.3)

IR, Incidence rates; LoS, Length of stay;
* The ratio of mean costs/length of stay incurred by infected patients compared to uninfected patients.
† The addition cost/length of stay incurred by infected patients compared to uninfected patients.
‡ Estimates derived from the regression analysis which controlled for age, sex, admission specialty, diagnosis, number of co-morbidities and admission type.

Table III *The incidence of hospital acquired infection by admission specialty and its impact on the length and cost of hospital stay*

Admission specialty	Incidence			Cost(£)				Length of stay (days)			
	No. of patients		IR% (95% CI)	Mean Cost		Ratio of cost* (model estimate: 95% CI)	Additional costs† (model estimate)‡	Means LoS		Ratio of LoS* (model estimate: 95% CI)‡	Additional days† (model estimate)‡
	No HAI	HAI		No HAI	HAI			No HAI	HAI		
Gynaecology	339	51	13.1 (9.9 to 16.8)	1661	2196	1.3 (1.3: 1.1 to 1.5)	535 (470)	6.1	8.3	1.4 (1.3: 1.1 to 1.6)	2.2 (2.0)
Elderly care	508	74	12.7 (10.1 to 15.7)	1748	5277	3.0 (3.1: 2.6 to 3.5)	3529 (3578)	11.3	34.7	3.1 (3.1: 2.6 to 3.7)	23.5 (23.9)
Obstetrics (caesarian sections only)	204	23	10.1 (6.5 to 14.8)	2481	2761	1.1 (1.1: 0.8 to 1.4)	280 (118)	7.5	8.6	1.2 (1.1: 0.8 to 1.4)	1.2 (0.5)
Orthopaedics	473	40	7.8 (5.6 to 10.5)	2089	5385	2.6 (2.6: 2.1 to 3.1)	3296 (3285)	10.4	22.6	2.2 (2.1:1.7 to 2.6)	12.3 (11.4)
Surgery	844	54	6.0 (4.5 to 7.8)	1290	6189	4.8 (3.9: 3.3 to 4.7)	4898 (3795)	5.4	23.1	4.3 (3.3: 2.7 to 4.0)	17.7 (12.4)
Urology	439	27	5.8 (3.9 to 8.3)	1276	2758	2.2 (2.2: 1.7 to 2.8)	1482 (1544)	5.1	14.0	2.7 (2.6: 2.0 to 3.4)	8.8 (8.2)
Medicine	800	38	4.5 (3.2 to 6.2)	1559	7271	4.7 (4.6: 3.8 to 5.6)	5712 (5621)	8.3	25.7	3.1 (3.0: 2.4 to 3.8)	17.3 (16.8)
Ear, nose & throat	64	2	3.0 (0.4 to 10.5)	2127	5644	2.7 (1.9: 0.8 to 4.6)	3516 (2007)	4.0	10.0	2.5 (2.2: 0.9 to 5.7)	6.0 (4.8)
All specialties	3671	309	7.8 (7.0 to 8.6)	1628	4782	2.9 (2.8: 2.6 to 3.0)	3154 (2917)	7.6	21.7	2.9 (2.5: 2.3 to 2.7)	14.1 (11.3)

See Table II for key.
* LoS = Length of stay

Table IV *The age, sex, admission type and admission specialty of patients recruited into the study compared to that which would have been obtained if all eligible patients had been recruited*

		Recruited patients		All eligible patients*	
		N	%	*N*	%
Sex	Males	1697	42.6	2669	45.5
	Females	2283	57.4	3199	54.5
	All patients	3980	100	5868†	100
Age group	18–59	1874	47.1	2720	47.2
	60+	2106	52.9	3040	52.8
	All patients	3980	100	5760‡	100
Admission type	Elective	1743	43.8	2332	39.6
	Emergency	2212	55.6	3499	59.4
	Unknown	25§	0.6	58	1.0
	All patients	3980	100	5889	100
Admission specialty	Medicine	838	21.1	1438	24.5
	Surgery	898	22.6	1442	24.6
	Orthopaedics	513	12.9	684	11.7
	Urology	466	11.7	712	12.1
	Obstetrics & gynaecology	617	15.5	713	12.2
	Elderly care	582	14.6	787	13.4
	ENT	66	1.7	90	1.5
	All patients	3980	100	5866¶	100

*This includes patients recruited into the study, patients who declined participation and patients who were eligible for recruitment but for reasons such as insufficient time the research assistant was unable to invite them to participate.

† An additional 21 patients were not recruited however their sex was not recorded, consequently they have been excluded from this analysis.

‡ An additional 129 patients were not recruited however their age was not recorded, consequently they have been excluded from this analysis.

§ These 25 in-patients were transfers from another ward.

¶ An additional 23 patients were not recruited however their admission specialty was not recorded, consequently they have been excluded from this analysis.

Estimates of the impact of HAI on hospital costs and length of hospital stay

Estimates of the impact HAI had on length of stay and hospital costs, and how these varied with site and specialty are also presented in Tables II and III. Patients presenting with one or more HAIs during the in-patient stay, on average, remained in hospital and incurred costs almost three times greater than uninfected patients. The distribution of the additional costs incurred between the budgetary centres of the provider unit is presented in Table V.

Estimates which only considered the costs of consumables, such as drugs, dressings and other pharmaceuticals, indicated that patients who acquired one or more infections which presented during the in-patient stay incurred consumable costs that were 3.7 (regression model estimate 3.8; 95% CI; 3.3, 4.2) times higher than those incurred by uninfected patients, equivalent to an increase of £315 (regression model estimate £325) per patient.

The estimated average increase in costs was lowest for urinary tract infections, with costs almost twice as high as in uninfected patients. The greatest increases were associated with multiple infections: on average costs were over six times higher than uninfected patients. With the exception of bloodstream infections, the impact of specific types of infection on length of hospital stay followed a similar pattern. The four patients who acquired a blood-stream infection and no other infection, had the lowest increase in length of stay; however, two of these patients died during the in-patient period. The results suggest that while these four patients were not found to have a marked increase in their length of stay, their hospital stay was highly resource-intensive. Specialty specific estimates indicated that HAIs occurring in obstetric patients who had had a caesarean section resulted in the lowest increase in length of stay and hospital costs, whereas infections occurring in surgical patients resulted in the highest increases.

Table V *Distribution of the hospital costs incurred by infected and uninfected patients during the in-patient phase*

Cost category	Mean costs (£)		Ratio of costs	Additional costs (£)	Percentage contribution to additional costs (%)
	No HAI N=3671	HAI N=309			
Hospital overheads	436.86	1112.58	2.5	675.72	21.43
Directorate management	49.90	115.07	2.3	65.18	2.07
Capital charges	207.80	499.68	2.4	291.88	9.26
Medical time	153.69	338.09	2.2	184.40	5.85
Nursing care	385.40	1721.25	4.5	1335.85	42.36
Paramedics & specialist nurses	17.46	63.70	3.6	46.24	1.47
Physiotherapy	19.02	93.35	4.9	74.34	2.36
Surgical interventions	195.20	263.44	1.3	68.24	2.16
Consumables used specific procedures*	9.95	118.35	11.9	108.40	3.44
Antimicrobials	13.40	71.07	5.3	57.67	1.83
All other drugs	40.99	150.46	3.7	109.47	3.47
Microbiology tests	6.97	33.13	4.8	26.16	0.83
Other pathology tests	48.26	113.34	2.3	65.08	2.06
Endoscopies	2.59	6.88	2.7	4.29	0.14
Radiology	35.19	73.13	2.1	37.94	1.20
Other tests	5.70	8.50	1.5	2.80	0.09
Total costs	1628.38	4782.03	2.9	3153.66	100

* This includes the cost of items such as dressings, drains, lines.

The national burden of HAI

Estimates of the number of patients who acquired an infection in hospital which presented during the in-patient period and of the economic burden these infections impose on the hospital sector are presented in Table VI.

An estimated 320 994 adult, non-day case admissions to the specialties covered in the underlying study in 1994/5 acquired one or more infections that presented during the in-patient period. These infections were estimated to cost the hospital sector £930.62 million (95% CI; £780.26, £1080.97 million).

The estimated burden varied considerably with the site of infection. While multiple infections, imposed the highest costs, urinary tract infections, which on average had a relatively low cost per case (model estimate £1122), due to their high incidence, were the most costly single site infection (£123.89 million; 95% CI; £80.96, £166.83 million). In contrast, bloodstream infections, which had a relatively high average cost per case (model estimate, £6209), imposed relatively low costs nationally (£25.53 million; 95% CI; −£6.86, £57.91 million). However, the confidence interval around this estimate is wide, reflecting the degree of uncertainty in the cost estimates derived.

Specialty specific estimates indicated that HAIs occurring in medical patients resulted in considerably greater costs than infections occurring in patients admitted to the other specialty groups.

Discussion

This study provides the most comprehensive UK estimate to date of the incidence and economic burden imposed by HAIs occurring in adult patients admitted to specialties common to most district general hospitals. At the national level, patients admitted to these specialties accounted for approximately 70% of all adult, non-day case admissions in 1994/5.[14] The remaining 30% were admitted to specialties not included in this study. The incidence and cost of infections occurring in these patients was not explored in this study.

Estimates of the incidence of HAIs indicated that 7.8% of patients who were recruited into the study and for whom complete data sets were obtained acquired one or more infections which presented during the in-patient period. As would be expected, this is less than the most recent prevalence figure of 9%[15] and interestingly is similar to the 7.2% incidence rate observed in the only other similar recent UK study.[3]

Table VI *Estimates of the number of adult patients, excluding day cases, admitted to selected specialties at NHS provider units throughout England, who acquired an infection in hospital in 1994/5, by site and by specialty and the economic burden imposed*

		Number of patients with an HAI which presented during the in-patient period (95% CI)		Estimated cost to hospital sector (95% CI) £ million		Estimated number of additional bed days (95% CI) days million	
All specialties and sites	All infections	320 994	(288 071–353 916)	930.62	(780.26–1080.97)	3.64	(3.01–4.27)
Site estimates – All specialties	Urinary tract	111 113	(90 537–131 690)	123.89	(80.96 –166.83)	0.59	(0.39–0.79)
	Multiple infections	57 614	(45 268–78 191)	507.77	(348.89–666.65)	1.70	(11.2–2.28)
	Lower respiratory tract	49 384	(37 038–65 845)	103.77	(59.41–148.12)	0.42	(0.21–0.63)
	Surgical wound	41 153	(28 807–53 499)	62.37	(30.93–93.82)	0.27	(0.12–0.41)
	Other sites	32 922	(20 577–45 268	75.87	(36.52–115.23)	0.38	(0.17–0.58)
	Skin	24 692	(16 461–37 038)	41.79	(15.40–68.17)	0.28	(0.11–0.45)
	Bloodstream	4 115	(0–12 346)	25.53	(–6.86–57.91)	0.02	(–0.02–0.05)
Specialty estimates – All sites	Gynaecology	65 683	(49 638–84 234)	30.55	(3.68– 57.42)	0.13	(0.02–0.25)
	Elderly care	54 776	(43 562–67 716)	196.29	(134.51–258.06)	1.31	(0.88–1.74)
	Obstetrics C/S only	8 493	(5 466–12 445)	1.05	(–4.97–7.07)	0.00	(–0.02–0.02)
	Orthopaedics	36 266	(26 037–48 820)	118.94	(64.65–173.23)	0.41	(0.19–0.63)
	Surgery	48 281	(36 210–62 765)	183.11	(117.40–248.82)	0.60	(0.37–0.83)
	Urology	12 974	(8 724–18 566)	20.03	(8.37–31.69)	0.11	(0.05–0.17)
	Medicine	64 439	(45 823–88 783)	362.66	(209.26–516.07)	1.08	(0.57–1.60)
	Ear, nose and throat	5 196	(693–18 188)	10.39	(–17.00–37.38)	0.02	(–0.04–0.09)

* The estimates are restricted to adult patients, excluding day cases, admitted to the specialties covered in the underlying study in 1994/5.

The incidence of HAIs varied with the site of infection. Urinary tract infections, as in other studies,[3,4,15] were found to be the most frequent single site infections followed by respiratory tract infections and surgical wound infections. Bloodstream infections were the least frequent type of infection with only four patients (0.1%) acquiring an infection at this site in the absence of other infections. With the exception of the multiple infection category, the incidence figures presented relate to the incidence of infections at a single site. If the site-specific incidence figures included both patients who had a single infection and those who also had infections at one or more other sites, the incidence figures would be higher in some cases. For example, whilst only four patients solely acquired a bloodstream infection, a further 11 patients acquired a bloodstream infection and one or more infections at other sites, giving an overall incidence of 0.4%.

Estimates of the economic burden imposed by HAIs indicate that they are a substantial drain on the hospital sector. Infected patients, on average, incurred hospital costs that were almost three times higher than those of uninfected patients and they remained in hospital 2.5 times longer. The majority of the additional costs incurred were linked to a prolonged hospital stay. This finding is consistent with that found in other studies.[5] Unlike earlier studies, however, we have presented detailed information on how costs were distributed amongst the budgetary centres of the hospital.

The additional costs imposed on the health sector varied considerably with the site of infection. Patients who acquired a urinary tract infection, and no other infection, as in other studies,[5–7] had the lowest increases in costs when compared with patients having infection at other sites, with costs, on average, 1.8 times higher than those of the uninfected patients. Patients who acquired more than one infection on average incurred the highest costs with hospital costs, on average, over six times higher than for uninfected patients.

In this study, regression analysis was used to control for a range of factors other than the presence of an HAI that may have had an impact on resource use. These were age, sex, admission specialty, admission type, diagnosis and number of comorbidities. This approach to attributing costs to HAI was selected in preference to the frequently used 'case-control' method.[2,5–7] This latter approach involves matching infected patients with one or more uninfected patients, on the basis of factors thought to influence resource use, and attributing the difference in costs incurred to the presence of an infection. It encounters a number of difficulties, in particular selecting appropriate matching factors and finding suitable control patients for all infected patients.[16–18]

The approach taken in this study to attribute resource use to the presence of an infection is also associated with difficulties, in particular whether the factors included in the regression modelling covered the major confounding factors. The possibility exists that factors other than those included in the analysis may have had an impact on the level of resource use. Additional analysis explored the impact of including three additional variables: social class; the average level of nursing care required during the period extending from admission to the time of infection; and a severity of illness measure (disease stage). This latter variable was derived from information about the patients' age, sex, diagnosis, co-morbidities, operation codes, admission type, length of in-patient stay and discharge destination. Previously validated algorithms[19] were used to allocate patients to one of three disease stage groups (low, medium and high) depending on the severity of their illness. This work was undertaken by CHKS Ltd using a specifically designed computer software programme. The inclusion of these additional variables was found to have very little effect on the estimated impact of HAI on hospital costs, once the other explanatory variables used, had been taken into account.[12]

The generalizability of the results of this study to other hospitals is dependent upon whether the case mix included in this study was typical of that which might be found in similar specialties at other hospitals, and how closely clinical practice, and the resource use and associated costs that this implies, reflects that occurring elsewhere.

A retrospective comparison of the study hospitals with other English NHS hospitals indicated that the study hospital was broadly representative of other hospitals in terms of bed days produced, number of staff employed and average length of stay. It was not possible to assess the representativeness of the case mix in any detail, or how typical clinical practice was of that found in other healthcare settings. It should be noted, however, that the specialties included in this study are common to most district general hospitals, and there was nothing to suggest that clinical practice would be markedly different elsewhere.

It was not possible to recruit all eligible patients. There is no reason to believe this may have biased the sample since a comparison of the age, sex, admission type and admission specialty distributions of the recruited cohort of patients, with that which would have been present if all eligible patients had been recruited, showed that there were very few differences. Due to this, and the fact that the infection group comparisons were made within the strata defined by these factors, and that these were not found to vary between strata, it is reasonable to assume that the results obtained are generalizable to all patients which this sample was intended to represent.

The estimates of the national burden of HAI are based on the observed incidence of HAI and the estimated economic burden imposed. The validity of the aggregated model is dependent upon the generalizability of these results. The analysis allowed for some variability in the incidence rates and ratios of costs incurred by infected compared to uninfected patients, based on the variance observed in the study data. The confidence limits around the national estimates reflects this. No adjustment was made for variation in the baseline cost associated with uninfected patients, nor for inflation. Although it is unclear how accurately the cost estimates associated with uninfected patients reflect costs at other hospitals, the study hospital, as indicated above, was found to be broadly representative of others in terms of the number of bed days produced, the number of staff employed and the average cost per bed day. Consequently, it is likely that the baseline estimates are a reasonable reflection of the costs elsewhere in 1994/5, when the study was conducted, but are likely to be higher today as a result of inflation.

The results presented indicate that a substantial number of adult, non-day case patients admitted to specialties common to most hospitals acquire one or more HAIs and that these infections are a considerable drain on limited hospital resources. In 1994/5 an estimated 320 994 patients acquired one or more HAIs costing the hospital sector an estimated £930.62 million, representing 9.1% of the in-patient acute, obstetric and geriatric programme budget in 1994/5,[20] and utilizing an estimated 3.64 million bed days, equivalent to an estimated 478 947 finished consultant episodes.

Given that these estimates are limited to adult, non-day case patients admitted to selected specialties, the actual burden is likely to be considerably greater than that indicated here. The incidence of HAIs occurring in some of the excluded specialties may be higher than that observed in this study, and in some cases are likely to impose a considerable additional burden. For example, infections occurring in patients undergoing renal transplant or cardiac surgery are likely to be particularly demanding of resources.

The estimates of both the number of patients who acquire one or more infections and the economic burden imposed, presented in this paper, are considerably higher than previously published estimates. For example in 1997, Glyn *et al.*[21] estimated that there were at least 100 000 HAIs annually, and in 1993 Coello *et al.*[5] estimated that HAIs occurring in surgical patients alone cost the NHS £170 million per annum. In this study HAIs occurring in surgical patients (surgical, orthopaedic, gynaecology, urology and ear, nose and throat patients) were estimated to cost the hospital sector £363 million.

The cost estimates derived in this study represent the average value of the resources that might be released if an infection is prevented, and the national estimates indicate the value of released resources if all infections were prevented. The estimates represent the gross benefits of prevention. Whilst not all HAIs can be prevented[22] the literature suggests that many could be prevented through improved infection control strategies.[2,10,23] Data from the United States suggests that a third of infections may be preventable.[23] However, the results of a recent census conducted by the National Audit Office reveal that whilst some infection control practitioners view this frequently quoted figure to be a realistic target, with some considering that a higher level of reduction could be achieved, a substantial proportion consider this to be rather ambitious. The average level of reduction thought to be achievable was 15%.[10]

If this modified target were achieved, considerable resources would be released for alternative use. For example, crude national estimates of the gross benefits of prevention, which take no account of which infections are prevented, suggest that a 15% reduction in HAIs would result in the release of hospital resources in the order of £140 million (95% CI; £117, £162 million). The majority of these released resources would be fixed in the cost structure of the hospital, with only 11% in the form of cash savings. Any benefits would therefore lie in their alternative use.

The same level of reduction would result in the release of an estimated 546 000 bed days (95% CI;

451 500, 640 500) In 1994/5 the average length of a finished consultant episode for the specialties covered in these estimates was 7.6 days.[14] It therefore follows that this is equivalent to an estimated 71 842 (95% CI; 59 407; 84 276) finished consultant episodes. Given the current length of waiting lists it appears that the value of these resources, if made available, would be great.

These models, whilst being gross simplifications of the complexities of determining the benefits of prevention, demonstrate that the prevention of HAIs should release considerable resources for alternative use. However, there are costs associated with prevention. Further work is now required to assess the cost and effectiveness of prevention activities and subsequently the net benefits of infection control.

Conclusion

The results presented in this paper indicate that HAI is a substantial problem both in terms of the incidence of this type of infection and the economic burden imposed on the hospital sector. Additional costs fall on the health sector post-discharge, patients and their carers. Estimates of the magnitude of these costs are reported elsewhere.[12]

The cost estimates presented represent the average value of resources that might be released if infections are prevented, and the national estimates, the gross benefits of preventing all infections. Not all infections are avoidable, however, and there are costs associated with prevention activities. The estimation of the net benefits of alternative prevention strategies was beyond the scope of this study. Further work is now required to establish the cost and effectiveness of these activities. This information may then be used together with the information presented in this paper to model the net benefits of infection control practices, the results of which may be used to inform infection control programmes.

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The Socio-economic Burden of Hospital Acquired Infection

EXECUTIVE SUMMARY

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Socio-economic burden of hospital-acquired infection

This report was submitted to the Department of Health in August 1997 and distributed for internal and external review. A full set of reviewers' comments was received in November 1997. A formal response was submitted to the Department of Health in February 1998, following which there was a period of discussion and debate. Further editing work and additional analysis was then undertaken. Amendments to the original text, together with the results of the additional analysis were submitted to the Department of Health in September 1998 and the report accepted for publication in September 1999.

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Introduction

At any one time approximately one in 10 patients in acute hospitals have a hospital-acquired infection (HAI) (DoH/PHLS, 1995). At the same time, an unquantified number of patients, discharged from hospital into the community, have an infection related to their recent hospital admission. These infections impose a burden on the secondary, tertiary and primary health-care sectors, community care services, the patients themselves and those who care for them. These burdens may be both financial and non-financial.

Studies that have estimated the cost of HAI generally focus on the burden to the hospital sector. Little is known about the costs incurred by the primary health-care sector, community care services, individual patients and their family and friends. These costs become increasingly relevant as the length of hospital stay becomes shorter and patients are discharged home at an earlier point in their recovery. This change in discharge pattern is likely to result in some treatment costs being shifted from the secondary health-care sector to the primary health-care sector and community care services, and may result in an increase in the costs borne by patients, their family and friends.

The aim of this research was to provide a more comprehensive assessment of the nature, distribution and magnitude of the costs resulting from HAIs. To achieve this, a detailed analysis of the resources used in hospital and post-discharge was undertaken.

The results of this research should be of use to both purchasers and providers of health care, in particular those involved in the planning and management of infection prevention and control programmes.

The research was commissioned by the Department of Health to the Central Public Health Laboratory and the London School of Hygiene and Tropical Medicine, and forms part of the Department of Health's Research and Development Programme.

Aims and objectives

The aim of the study was to assess the burden of HAI in terms of the costs to the public sector, patients, informal carers and society as a whole. Specific objectives were to:

1. Determine the overall burden of HAI in terms of the:
   - Costs to the secondary and primary health-care sectors and community care services.
   - Impact on the health status of patients.
   - Costs to patients, informal carers and the economy.
2. Establish the relative costs of different types of HAI.
3. Determine the type of patients who incur the highest costs for specific infections.
4. Use the data obtained to construct models to predict the effects of HAI on the cost categories described above.

Research methods

Adult patients with a minimum in-patient stay of 30 hours were recruited from the general wards of a district general hospital over a 13-month period between April 1994 and May 1995. Information on daily resource use was recorded for each patient for the duration of their hospital stay. Patients who presented with signs and symptoms of infection which met the definitions of infection used in this study, and a sample of patients who did not, were followed up post-discharge using a structured questionnaire. This questionnaire provided information on possible surgical wound, chest and urinary tract infections experienced after discharge from hospital; care received from health and community care services, family and friends; personal expenditure on items such as drugs and dressings; time of return to normal activities and, if applicable, employment; and information on the patients' health status following discharge from hospital. Information about care received post-discharge was also obtained from the patients' health-care records. Estimates of the cost of the resources used were made and analysed to determine the extent to which observed variations in costs incurred by infected and uninfected patients could be explained by the presence of an HAI.

The in-patient analysis considered how resource use and associated costs varied between patients with and without an HAI, and how these outcome measures varied with site of infection. The post-discharge analysis considered how costs varied between four patient groups:

- Patients who did not have an HAI identified during the in-patient phase or an infection identified post-discharge (Group 1).

- Patients who did not have an HAI identified during the in-patient phase, but reported symptoms and treatment that met the study criteria for one or more infections present post-discharge (Group 2).
- Patients who had one or more HAIs identified during the in-patient phase, but did not report symptoms and treatment that met the study criteria for one or more infections present post-discharge (Group 3).
- Patients who had one or more HAIs identified during the in-patient phase, and reported symptoms and treatment that met the study criteria for one or more infections present post-discharge (Group 4).

Patients were classified as having a possible infection post-discharge if they reported symptoms and treatment which met the criteria for surgical wound, chest or urinary tract infections used in this study. It was not possible to determine whether in all cases an infection was present, or whether it was acquired in hospital. Furthermore, where patients presented with an HAI in hospital, it was not clear whether the symptoms reported post-discharge represented a new infection or a continuation of a previously diagnosed infection.

Since factors other than the presence of an HAI may have accounted for some of the additional resource use and costs incurred by infected patients, resource and cost outcome measures were analysed using regression modelling which controlled for a range of potential confounders (age, sex, diagnosis, number of co-morbidities, admission specialty, admission type and, where appropriate, time of return of questionnaire). Estimates allowing for the effects of these confounders were subsequently derived from this modelling process.

Results

Recruitment and post-discharge response rates

- Four thousand adult patients were recruited into the study from the medical, surgical, orthopaedic, urology, gynaecology, ear, nose and throat (ENT), elderly care and, if they had a caesarean section, obstetric specialties.
- Complete in-patient data sets were obtained for 3980 patients.
- A total of 1449 patients were selected for follow-up into the community: 215 had an infection identified during the in-patient phase.
- Of those patients selected for follow-up, 41 died either before the first questionnaire was sent at four weeks post-discharge, or between the distribution of the first and second questionnaires at eight weeks post-discharge. Four of these patients had an HAI identified during the in-patient phase. All 41 patients were excluded from the response rate.
- Seventy-one per cent of patients returned the questionnaire after a maximum of two reminders.
- The response rate was similar for patients with and without an HAI identified during the in-patient phase.

Incidence of HAIs

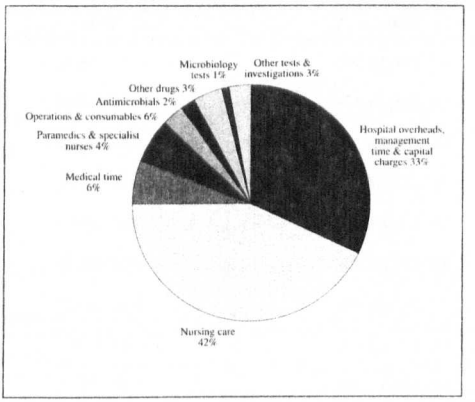
- In-patient phase: 7.8% (95% CI: 7.0; 8.6) of patients were identified during the in-patient phase as having acquired one or more HAIs.
- Post-discharge phase: 19.1% (95% CI: 16.5; 21.9) of those patients who returned the questionnaire and who did not have an HAI identified during the in-patient phase and 30% (95% CI: 22.8; 38.0) of patients who had an HAI identified during the in-patient phase reported symptoms and treatment that met the criteria for a urinary tract, chest and/or surgical wound infection used in this study.

Impact of HAI on hospital costs incurred during the in-patient phase

Patients who presented with one or more HAIs during their in-patient stay were found to incur costs that were, on average, 2.9 times greater than those for uninfected patients. In these study patients, this represented an absolute increase of £3154 per case. After adjusting for the effects of potential confounders the ratio was almost identical (2.8; 95% CI: 2.6; 3.0), suggesting that confounding had relatively little effect.

Hospital overheads, capital charges and the cost of management time accounted for 33% of the additional costs incurred, while nursing care accounted for 42%, medical care 6%, operations and consumables 6%, paramedics and specialist nurses 4%, antimicrobials 2%, other drugs 3%, microbiology tests 1%, and other tests and investigations 3% (see Figure 1).

Figure 1. The distribution of the additional costs incurred by patients with one or more HAIs compared with uninfected patients during the in-patient hospital stay



The mean costs of treating infected and uninfected patients varied with specialty. Table 1 (page 4) shows the mean costs incurred, the ratio of the costs incurred by infected patients compared with uninfected patients, and the additional costs incurred by infected patients in this study. The figures in parentheses are the estimates obtained from the regression analysis.

Impact of specific types of HAI on hospital costs incurred during the in-patient phase

The impact that HAIs had on hospital costs varied with the site of infection. Table 2 (page 4) shows the mean costs incurred, the ratio of the costs incurred by infected patients compared with uninfected patients, and the additional costs incurred by infected patients. The figures in parentheses are the estimates obtained from the regression analysis.

Infections of the urinary tract were found to be the least expensive, with costs, on average, 1.8 times higher than those for uninfected patients. In these patients, this is, on average, equivalent to an additional £1327 per patient.

Patients who acquired infections of the lower respiratory tract, skin, surgical wound or 'other' sites experienced similar patterns of increase in costs. Costs were, on average, two to 2.5 times greater than those incurred by uninfected patients, equivalent to an average increase of between £1618 and £2398 per patient.

The four patients who acquired bloodstream infections incurred costs that were, on average, over four times those for uninfected patients. In these patients, this is equivalent to an additional £5397 per patient. However, since there were only four patients in this infection group, two of whom died, general conclusions based on these results must be treated with caution.

Patients who acquired more than one HAI incurred the highest expenses, with costs, on average, 6.6 times greater than those incurred by uninfected patients. In these patients, this is equivalent to an additional £9152 per patient.

For all sites of infection, adjustment for potential confounders made little difference and the relative magnitudes of effects were almost entirely unchanged.

Impact of HAI on length of hospital stay

Patients who acquired an infection in hospital remained in hospital, on average, 2.9 times longer than uninfected patients, equivalent to an extra 14 days. After adjusting for other factors that might influence length of stay, the ratio of increase was modified to 2.5 (95% CI: 2.3; 2.7), which is, on average, equivalent to an extra 11 days.

Impact of specific types of HAI on length of hospital stay

The extended hospital stay experienced by patients with an HAI varied with site of infection (Table 3, see page 5). Patients who acquired more than one infection were observed to have the greatest increase in mean length of stay. Patients with bloodstream infections had the lowest increase. However, as mentioned above, there were only four patients in this group, two of whom died while still in hospital.

Impact of HAI on the health-care sector post-discharge

With the exception of patients who presented with an HAI as an in-patient and did not have an infection identified post-discharge, who on average incurred lower GP costs than patients in the other infection groups, patients who had an HAI identified during the in-patient phase, and/or an infection identified post-discharge, on average, had greater contact with their GP, visited the hospital more frequently for outpatient appointments and received more visits from district nurses compared with uninfected patients. Patients who acquired an infection therefore imposed an additional economic burden on these services. Acquiring an infection was not found to have a positive impact on the number or cost of health

Table 1. Mean costs incurred during the in-patient phase by patients with and without an HAI and by admission specialty

Specialty	Mean costs (£)				Ratio of costs (model estimate; 95% CI)	Additional costs (£) (model estimate)
	No HAI (a)	n	HAI (b)	n	(b/a)	(b-a)
Medicine	1559	800	7271	38	4.7 (4.6; 3.8, 5.6)	5712 (5621)
Surgery	1290	844	6189	54	4.8 (3.9; 3.3, 4.7)	4898 (3795)
Orthopaedics	2089	473	5385	40	2.6 (2.6; 2.1, 3.1)	3296 (3285)
Urology	1276	439	2758	27	2.2 (2.2; 1.7, 2.8)	1482 (1544)
Gynaecology	1661	339	2196	51	1.3 (1.3; 1.1, 1.5)	535 (470)
Elderly care	1748	508	5277	74	3.0 (3.1; 2.6, 3.5)	3529 (3578)
ENT	2127	64	5644	2	2.7 (1.9; 0.8, 4.6)	3516 (2007)
Obstetrics*	2481	204	2761	23	1.1 (1.1; 0.8, 1.4)	280 (118)
Overall	1628	3671	4782	309	2.9 (2.8; 2.6, 3.0)	3154 (2917)

*Caesarean sections only

Table 2. Mean costs incurred during the in-patient phase by site of HAI

Site of infection	Mean costs (£)	n	Ratio of costs (model estimate; 95% CI)	Additional costs (£) (model estimate)
No HAI	1628	3671		
UTI	2955	107	1.8 (1.7; 1.5, 1.9)	1327 (1122)
LRTI	4027	48	2.5 (2.3; 1.9, 2.7)	2398 (2080)
SWI	3246	38	2.0 (2.0; 1.6, 2.4)	1618 (1594)
BSI	7026	4	4.3 (4.8; 2.6, 8.8)	5397 (6209)
Skin	3418	25	2.1 (2.0; 1.6, 2.5)	1790 (1615)
Other	3892	30	2.4 (2.5; 2.0, 3.1)	2263 (2465)
Multiple	10780	57	6.6 (6.3; 5.4, 7.4)	9152 (8631)
Any infection	4782	309	2.9 (2.8; 2.6, 3.0)	3154 (2917)

UTI=urinary tract infection; LRTI=lower respiratory tract infection; SWI=surgical wound infection; BSI=bloodstream infection

visitor and community midwife visits. Table 4 (page 5) summarises the impact of HAI on health sector costs post-discharge. The mean costs incurred by patients in the four HAI groups are presented, together with the ratio of the costs incurred by infected patients compared with uninfected patients and the additional costs incurred by infected patients. The figures in parentheses are the estimates obtained from the regression analysis.

General practitioners

Patients who did not present with an HAI while in hospital but reported symptoms and treatment that met the study criteria for an infection post-discharge, and patients who developed an HAI while in hospital and had an infection identified post-discharge, on average, incurred proportionally greater costs than patients in the other two groups. However, the average increases in the absolute costs observed were minimal.

Table 3. Mean length of hospital stay by site of HAI

Site of infection	Mean LoS (days)	n	Ratio (model estimate; 95% CI)	Additional days (model estimate)
No HAI	8	3671		
UTI	14	107	1.8 (1.7; 1.5, 1.9)	6 (5)
LRTI	20	48	2.6 (2.1; 1.7, 2.6)	12 (8)
SWI	14	38	1.9 (1.9; 1.6, 2.4)	7 (7)
BSI	10	4	1.2 (1.5; 0.8, 3.0)	2 (4)
Skin	20	25	2.6 (2.4; 1.8, 3.1)	12 (11)
Other	21	30	2.8 (2.6; 2.1, 3.4)	13 (12)
Multiple	45	57	6.0 (4.8; 4.0, 5.8)	38 (29)
Any infection	22	309	2.9 (2.5; 2.3, 2.7)	14 (11)

LoS=length of stay; UTI=urinary tract infection; LRTI=lower respiratory tract infection; SWI=surgical wound infection; BSI=bloodstream infection

Table 4. Impact of HAI on health sector costs incurred post-discharge

One or more HAIs identified during the in-patient phase	One or more infections identified post-discharge	n	Health-care professional visited*	Mean observed costs (£)	Ratio of costs (model estimate; 95% CI)	Additional costs (£) (model estimate)
No	No	664	GP	18	—	—
		658	HD/HN	32	—	—
		558	DN	34	—	—
No	Yes	159	GP	28	1.6 (1.7; 1.3, 2.3)	10 (12)
		160	HD/HN	39	1.2 (1.9; 1.3, 2.6)	7 (28)
		130	DN	39	1.2 (1.5; 1.0, 2.1)	6 (16)
Yes	No	99	GP	14	0.8 (0.8; 0.5, 1.1)	-4 (-4)
		102	HD/HN	36	1.1 (1.3; 0.9, 2.0)	4 (11)
		89	DN	59	1.8 (1.6; 1.0, 2.3)	25 (19)
Yes	Yes	43	GP	24	1.4 (1.5; 0.9, 2.6)	6 (10)
		43	HD/HN	40	1.3 (2.7; 1.5, 4.7)	8 (53)
		39	DN	78	2.3 (2.6; 1.4, 4.7)	44 (53)

*Sources: GP and HD/HN (the post-discharge questionnaire); DN (the DN database)

GP=general practitioner; HD/HN=hospital doctor/hospital nurse; DN=district nurse

Hospital doctor/nurse

Patients who did not present with an HAI while in hospital but had an infection identified post-discharge, and patients who presented with an HAI while in hospital and had an infection identified post-discharge incurred slightly higher costs than patients in the other two categories.

District nurses

Patients who had an HAI identified during the in-patient phase, and/or an infection identified post-discharge, on average, had a greater impact on district nursing costs compared with uninfected patients. Patients who presented with an HAI as an in-patient and had an infection identified post-discharge had the greatest impact on district nursing costs.

The results from the regression analysis suggest there was some confounding and that the effects of HAI on GP, district nursing and hospital costs in a number of cases were probably larger than those observed.

Impact of HAI on costs incurred by patients

Personal expenditure on items such as drugs and dressings was found to vary with HAI group. The mean costs incurred by patients in the four HAI groups are presented in Table 5, together with the ratio of the costs incurred by infected patients compared with uninfected patients and the additional costs incurred by infected patients. The figures in parentheses are the estimates obtained from the regression analysis.

Increases in personal expenditure were greatest for patients who presented with an HAI as an in-patient and had an infection identified post-discharge. These patients experienced costs that were 3.2 times greater than those incurred by uninfected patients. Adjustment for potential confounders made little difference and the relative magnitudes of effect remained similar to the observed effects.

Impact of HAI on the number of days from admission to return to normal daily activities

The number of days from admission to resuming normal daily activities varied with HAI group. The mean number of days from admission to resuming normal daily activities for patients in the four infection groups are presented in Table 6, together with the ratio of the number of days infected patients were away from normal daily activities, compared with uninfected patients. The additional number of days that infected patients took to resume normal daily activities, compared with uninfected patients, are also presented.

Patients who had an HAI identified during the in-patient phase and/or an infection identified post-discharge, on average, took longer to resume normal daily activities than patients in the uninfected group. Patients who had an HAI identified during the in-patient period and reported symptoms and treatment that met the criteria for an infection post-discharge took longer to resume normal daily activities than patients in the other infection groups.

Table 5. Impact of HAI on personal costs incurred by patients

One or more HAIs identified during the in-patient phase	One or more infections identified post-discharge	n	Mean observed costs (£)	Ratio of costs (model estimate; 95% CI)	Additional costs (£) (model estimate)
No	No	691	9	—	—
No	Yes	163	15	1.7 (1.5; 1.1, 1.9)	6 (4)
Yes	No	105	5	0.5 (0.9; 0.6, 1.3)	-4 (1)
Yes	Yes	45	30	3.2 (3.2; 2.0, 5.0)	20 (20)

Table 6. Mean number of days from admission to return to normal daily activities by HAI status

One or more HAIs identified during the in-patient phase	One or more infections identified post-discharge	n	Mean no. of days	Ratio of days (model estimate; 95% CI)	Additional days (model estimate)
No	No	642	29		
No	Yes	155	35	1.2 (1.2; 1.1, 1.4)	6 (6)
Yes	No	94	41	1.4 (1.4; 1.3, 1.6)	12 (13)
Yes	Yes	43	43	1.5 (1.6; 1.3,1.9)	13 (17)

Impact of HAI on the number and value of days employed patients were away from paid employment

The number and value of days from admission to return to paid employment varied with HAI group. The mean number and value of days from admission to return to paid employment for patients in the four infection groups are presented in Tables 7–8, together with the ratio of the number and value of days infected patients were away from employment, compared with uninfected patients. The additional number of days infected patients were away from paid employment, compared with uninfected patients, are also presented.

Patients who had an HAI identified during the in-patient phase and/or an infection identified post-discharge had a greater number of days away from employment than uninfected patients.

Impact of HAI on the number of days informal carers spent caring for patients and their dependants

The number and value of days informal carers spent caring for the patient's dependants during the in-patient period and the patient post-discharge varied with HAI group. The mean number of days of care provided by informal carers for patients in the four infection groups are presented in Table 9 (page 8) and the estimated value of this time is presented in Table 10 (page 8). The ratio of the number of days of care received by infected compared with uninfected patients and the associated value, together with the number of additional days of care received by infected compared with uninfected patients, are also presented in these tables.

Patients who reported symptoms and treatment that met the study criteria for one or more infections present post-discharge, regardless of whether they presented with an infection in hospital, on average, received more care from informal carers than patients who had not acquired an infection, or who presented with an infection in hospital but did not have an infection identified post-discharge.

Impact of HAI on health status

The responses given to the general health status questionnaire, the SF-36, administered four weeks post-discharge, provided information on eight dimensions of health. Two summary measures relating to physical and mental well-being were derived from these data. Patients

Table 7. Mean number of days from admission to return to employment by HAI status

One or more HAIs identified during the in-patient phase	One or more infections identified post-discharge	n	Mean no. of days	Ratio of days (model estimate; 95% CI)	Additional days (model estimate)
No	No	267	23		
No	Yes	66	29	1.2 (1.1; 1.0, 1.3)	6 (2)
Yes	No	30	29	1.3 (1.2; 1.0, 1.5)	6 (6)
Yes	Yes	11	28	1.2 (1.3; 0.9, 1.7)	5 (6)

Table 8. Mean value of days from admission to return to employment by HAI status

One or more HAIs identified during the in-patient phase	One or more infections identified post-discharge	n	Mean value of days	Ratio of costs (model estimate; 95% CI)	Additional costs (£) (model estimate)
No	No	267	1429		
No	Yes	66	1724	1.2 (1.1; 1.0, 1.3)	295 (200)
Yes	No	30	1649	1.2 (1.2; 1.0, 1.5)	220 (300)
Yes	Yes	11	1889	1.3 (1.6; 1.1, 2.2)	460 (801)

Table 9. Mean number days informal carers spent caring for dependants and patients by HAI status

One or more HAIs identified during the in-patient phase	One or more infections identified post-discharge	n	Mean no. of days	Ratio of days (model estimate; 95% CI)	Additional days (model estimate)
No	No	691	10.3		
No	Yes	163	14.4	1.4 (1.2; 1.0, 1.6)	4.1 (2.1)
Yes	No	105	10.5	1.0 (0.9; 0.6, 1.2)	0.2 (-1.3)
Yes	Yes	45	20.9	2.0 (1.6; 1.0,2.5)	10.6 (6.1)

Table 10. Mean value of days informal carers spent caring for dependants and patients by HAI status

One or more HAIs identified during the in-patient phase	One or more infections identified post-discharge	n	Mean value of days (£)	Ratio of costs (model estimate; 95% CI)	Additional costs (£) (model estimate)
No	No	691	348		
No	Yes	163	488	1.4 (1.3; 0.8, 2.1)	140 (96)
Yes	No	105	355	1.0 (0.7; 0.4, 1.3)	7 (-100)
Yes	Yes	45	707	2.0 (2.3; 0.9, 5.6)	359 (454)

with an HAI, on average, obtained lower scores for these two measures than patients who did not acquire an infection, indicating a poorer outcome as determined by these health measures. Patients who presented with an HAI as an in-patient and reported symptoms and treatment which met the study criteria for an infection present post-discharge, on average, reported the lowest health status.

Impact of HAI on in-patient mortality

The in-patient death rate was found to be considerably higher in patients with an HAI which presented during the hospital stay: 13% of patients with an HAI died compared with 2% of patients who did not present with an HAI in hospital. After adjustment for the effects of age, sex, diagnosis, number of co-morbidities, admission specialty and admission type, patients with an HAI were found to be 7.1 (95% CI: 4.3; 11.7) times more likely to die in hospital than uninfected patients.

Estimates were made of the number of years of life lost by infected patients who died. Patients aged 25–44 years who acquired an infection in hospital and subsequently died, on average, lost 44 years; patients aged 45–64 lost 19 years, patients aged over 65–84 years lost 11 years, and patients aged 85 years and over lost 4 years. Since it was not possible to determine for each individual case whether the HAI was the primary cause of death, a contributing factor, or whether it made no contribution to the death, neither the number nor value of the years of life lost as a result of an HAI could be determined. However, it is important to acknowledge that years of life lost do have a value and represent an important cost associated with HAI.

National estimates

The study results were used to estimate the economic burden of HAIs occurring in adult (≥18 years) patients, excluding day cases, admitted to the specialties covered in this study throughout England. Patients admitted to these specialties accounted for approximately 70% of adult, non-day case NHS admissions in England in 1994–1995.

The results presented are based on the assumption that the incidence of HAI, the ratio of increase in costs incurred by infected compared with uninfected patients and the mean cost of treating uninfected patients observed in this study are representative of the incidence and costs incurred by patients admitted to the specialties covered in this study throughout England.

Estimates of the economic burden of HAI to the NHS in England

HAIs were estimated to cost the NHS in England £986.36 million annually. Of this aggregate cost, £930.62 million (95% CI: £780.26; £1080.97 million) was estimated to have been incurred during the patients' hospital stay and £55.74 million post-discharge. These post-discharge costs were distributed between GPs (£8.4 million), hospitals (outpatient consultations) (£26.83 million) and district nursing services (£20.51 million). The estimates of the effect of HAI on health sector costs incurred post-discharge varied considerably, depending on whether the HAI presented during the in-patient and/or post-discharge phase. The 95% confidence intervals obtained for the different infection groups were wide and this should be taken into account when using these estimates.

The in-patient hospital estimates represent 9.1% of the acute, geriatric and obstetric programme budget for 1994-95, and estimates of the cost to the hospital sector post-discharge 0.9% of the outpatient acute, geriatric and obstetric programme budget for the same year (data from Department of Health). The estimated burden to GPs represents 0.3% of the general medical services budget for 1994-95 (data from the Department of Health) and the estimated burden to district nursing services represents 2.4% of their budget for the same year (data from the Department of Health).

Table 11 presents estimates of the impact of specific types of infection on in-patient costs. The cost estimates are limited to those incurred by the hospital sector during the in-patient stay. Nationally, infections of the urinary tract were estimated to be the most expensive single-site infection, costing an estimated £123.89 million per annum (95% CI: £80.96; £166.83). These infections were relatively inexpensive to treat (the additional cost per case observed in this study was £1327, model estimate £1122), but their relatively high incidence means that, nationally, they impose a substantial burden on the NHS. No attempt was made to derive site-specific estimates of the impact of HAI on health sector costs incurred post-discharge.

Table 11. National estimates of the burden of HAI to the hospital sector in England by site of infection (in-patient costs only*)

Site of infection	Estimates of the national burden of HAI Figures expressed in £ (millions)		
	Estimate	95% CI	
		Low	High
UTI	123.89	80.96	166.83
LRTI	103.77	59.41	148.12
SWI	62.37	30.93	93.82
BSI	25.53	-6.86	57.91
Skin	41.79	15.40	68.17
Other	75.87	36.52	115.23
Multiple	507.77	348.89	666.65

UTI=urinary tract infection; LRTI=lower respiratory tract infection; SWI=surgical wound infection; BSI=bloodstream infection

*Estimates are limited to the additional costs incurred as a result of HAIs occurring in adult patients, excluding day cases, admitted to the specialties covered in this study: approximately 70% of all adult, non-day case NHS admissions

Estimates of the economic burden of HAI to patients

Personal expenditure on items such as drugs and dressings incurred by patients who acquire an infection in hospital are estimated to amount to £4.74 million annually. The estimates derived varied considerably depending on whether the patient presented with an HAI in hospital and/or had an infection identified post-discharge. The confidence intervals derived for each HAI group were wide and this should be taken into account when using these estimates.

Estimates of the number of extra days patients took to resume normal daily activities

Nationally, patients who acquire an infection in hospital, when compared with uninfected patients, were estimated to take an additional 8.7 million days to resume normal daily activities. The estimates varied considerably with HAI group and the 95% confidence intervals were wide. These factors should be taken into account when considering these estimates.

The benefits of prevention

This study was not directly concerned with estimating the benefits of prevention. However, the estimates presented provide important information on the value of resources that might be released for alternative use if a proportion of infections are prevented. These may be viewed as the gross benefits of prevention. Net benefits will depend on the cost and effectiveness of prevention activities.

Estimates of the gross benefits which may result from a 10% reduction in the observed incidence rate, both in terms of the benefits to the study hospital and to provider units throughout England, are presented in the report. In addition to estimates of the value of resources released for alternative use, the value of consumables released and the number of bed days released are presented.

At the level of the study hospital, a 10% reduction in the observed incidence rate was estimated to result in the release of resources valued at £361 297 (95% CI: 302 924; 419 670). A similar reduction at the national level was estimated to result in the release of resources valued at £93.06 million (95% CI: 78.03; 108.10 million).

In the short term, only a relatively small proportion of these benefits are likely to be in the form of cash savings. However, over a longer period of time it is possible that some of the fixed costs might be avoided and, as such, the proportion of benefits that may accrue as cash benefits may increase.

In terms of the number of bed days released for alternative use, at the level of the study hospital a similar level of reduction may result in an estimated 1413 (95% CI: 1168; 1659) bed days released for alternative use; equivalent to an estimated 191 finished consultant episodes (95% CI: 158; 224). At the national level, 364 056 (95% CI: 300 880; 427 223) bed days may be released; equivalent to an estimated 47 902 finished consultant episodes (95% CI: 39589; 56214).

These estimates, although considerable, may be conservative estimates of the value of resources that might be released. They are limited to the benefits that may result from a reduction in the incidence of HAI occurring in adult patients admitted to the specialties covered in this study, and are based on a 10% reduction in the incidence rate. The literature suggests that up to 30% of HAIs may be prevented through effective infection control programmes (Haley, 1986).

Discussion

The results of this study clearly indicate that HAIs impose a substantial burden on the secondary and primary health-care sectors, on infected patients and their informal carers. A detailed analysis of the effect of HAI on resource use and costs was undertaken, the results of which provide important information on the nature, magnitude and distribution of the economic burden. The approach taken is considerably more detailed than earlier studies which have generally limited the analysis of costs to those incurred by the hospital sector and have not attempted to determine the distribution of these costs in any great detail.

Three main points should be borne in mind when interpreting these findings.

First, attributing costs to the presence of an HAI is extremely complex. The characteristics of patients with an HAI may differ systematically from those of uninfected patients. If these differences result in additional resource use, this would bias the estimates of the effects of HAIs. The in-patient regression analysis showed this was not the case for age, sex, admission type, specialty, diagnosis and co-morbidities. Nonetheless, the possibility that there may be some other confounding factors cannot be completely ruled out. For example, due to factors not included in the regression analysis, patients with an HAI may have remained in hospital longer than similar patients who did not acquire an infection, regardless of whether they acquired an infection or not. An analysis investigating this possibility revealed some evidence that the difference in length of stay between patients with and without an HAI was not due entirely to the infection. Consequently, the estimates of the effect of HAI on length of stay and the associated costs may be biased. However, estimates of the magnitude of this bias were very sensitive to the strong simplifying assumptions on which they were based and, as such, it would be unwise to conclude more than that the estimated effects of HAI on length of hospital stay presented may include an upward bias. The post-discharge regression analysis indicated that there was some confounding and that the effects in a number of cases were probably larger than those observed in the unadjusted figures.

Second, the study was restricted to patients admitted to one NHS trust over a 13-month period. Future patients admitted to this and other NHS trusts might differ in various ways. In addition, estimates of the costs of resources used were, in most cases, specific to this NHS trust, and

clinical practice affecting resource use might differ with time and with provider unit. However, it seems reasonable to assume that any differences that occur will be the same for patients with and without an HAI. On this assumption, the proportion by which an HAI increases resource use will not be affected and, consequently, the proportional effects estimated from this study will be generalisable. Absolute increases in costs incurred by infected patients may differ with time and with provider unit. However, since the study hospital was found to be broadly similar to other provider units in terms of factors such as average length of stay and average cost per bed day, it is reasonable to assume that the estimated effects of HAI on absolute costs are also fairly generalisable.

Third, when considering both the gross and net benefits of prevention, it is important to realise that any savings represent a reduction in individual treatment costs and not necessarily an overall saving to the health sector. This will depend on how released resources are utilised and this will, to some extent, depend on the structure of the contracts and agreements in place. If, for example, the prevention of infection results in a reduction in length of hospital stay, bed days will be released for alternative use. If these released bed days are utilised by more expensive patients then, rather than resulting in a cost saving for the NHS, overall expenditure will increase. However, this will be offset by benefits gained by the extra patients treated.

Conclusion

The results of this study provide a detailed account of the socio-economic burden imposed by HAIs occurring in adult patients admitted to selected specialties common to most NHS provider units. It represents the first comprehensive attempt to estimate these costs. The results provide valuable information that might be used at national and local level to inform the management of HAI and, when used alongside effectiveness studies of infection prevention and control measures, will facilitate the development of effective policies to control HAI.

Recommendations

Specific recommendations arising from this research

Commissioners of health care (purchasing agencies) should:

- Be aware of the magnitude of the overall burden imposed by HAI and how it is distributed.
- Ensure adequate details on infection control arrangements and ongoing strategies for the prevention of infection are in place in all provider units with which they contract.
- Recognise that, in a number of cases, HAIs present after discharge from hospital, and that these infections should be monitored and the needs of affected patients met.

Providers of health care should:

- Use the findings of this study, together with information on the effectiveness of different infection control activities, to inform infection prevention and control strategies within their provider unit.
- Ensure appropriate arrangements are in place to monitor infections presenting post-discharge and the needs of affected patients are met.

Educational institutions involved in the education of health care personnel should:

- Include the socio-economic burden imposed by HAI in their educational programmes on HAI and in so doing raise awareness of the issues relating to HAI and the importance of infection prevention and control strategies.

Further research and development

During the course of this study a number of areas which would benefit from further research and development were identified. These are briefly presented below.

The first area that requires some further work relates to how generalisable the results of this study are to future patients in other health-care settings. For reasons discussed above, it seems reasonable to assume that the results are generalisable, but further work will be carried out to assess in greater detail whether the pattern of

resource use observed in this study is broadly similar to that found in other provider units. It is also recommended that further methodological work be undertaken to increase knowledge of how best to estimate the cost of hospital services.

Attributing costs to the presence of an HAI presented a number of methodological difficulties. In this study, regression analysis was used to control for a range of factors. However, as discussed above, factors not included may have had an impact on resource use and costs. For example, patients with an HAI may have remained in hospital longer than uninfected patients due to factors other than those included in the regression analysis. An analysis has been undertaken to investigate this, but the results were sensitive to the strong simplifying assumptions on which the analysis was based. It is therefore recommended that further work on the complex relationship between length of stay and HAIs be undertaken to assess more precisely what part of the length of stay can be ascribed to the effect of HAI and the associated costs.

Following discharge from hospital, patients with an HAI were found to make more visits to their GP and/or doctor or nurse at the hospital than uninfected patients. Consequently, infected patients had a greater economic impact on these health-care services than uninfected patients. The analysis to date has not taken into account the resource intensity of these visits. It is possible that visits made by patients with an HAI were more resource-intensive, and thus the economic impact was greater, than that estimated in this study. It is therefore recommended that the data obtained in this study be further analysed to determine the resource intensity of visits made to GPs and hospital doctors/nurses, and how this varies between patients with and without an HAI. It is also recommended that further work be conducted to determine whether the health needs of patients experiencing HAIs in the community are being met.

Acquiring an HAI in hospital was associated with a reduction in mental and physical well-being, as measured by the SF-36. It is recommended that further work be carried out to explore the nature and reasons for the apparent reduction in mental and physical well-being observed in patients with an HAI compared with uninfected patients, and that the results of this work are used, where possible, to inform clinical practice.

As part of this study, a decision support system to model and predict the effects of HAI on components of resource use and their costs within different provider units was developed. It is recommended that this system be further developed to create a user-friendly decision support mechanism which meets the information needs of both purchasers and providers of health care.

The results of this study provide information on the nature, distribution and magnitude of the burdens imposed by HAI. These burdens represent the potential gross benefits of prevention. Further work is required to determine the cost-effectiveness of selected infection control practices. The information derived may then be used to inform infection control practice and the overall allocation of resources to infection control.

Finally, the results of this study relate to adult patients, excluding day cases, admitted to the general specialties of a district general hospital. Patients admitted to these specialties accounted for approximately 70% of adult, non-day case NHS admissions in 1994–95. It is recommended that future work examine the socio-economic burden of HAIs occurring in the other patient groups, in particular in patients at high risk of acquiring an infection in hospital (e.g. babies cared for in special care baby units) and patients undergoing major and specialised surgery (e.g. cardiothoracic surgery and organ transplantation).

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