FINAL VERSION

Demand and capacity for carbapenemase-producing Enterobacteriaceae screening in a West London hospital network

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ABSTRACT

Background

Numerous screening and isolation strategies have been developed to address the rising trend in carbapenemase-producing Enterobacteriaceae (CPE). Yet, potential mismatches between demand for CPE screening and capacity are a threat to implementation. This study estimates the demand in (i) testing and (ii) inpatient days requiring contact precautions, if all inpatients in high risk specialties were screened for CPE in a West London hospital network.

Methods

Clinical specialties in three teaching hospitals were ranked by prevalence of carbapenem-resistant *Escherichia coli* and *Klebsiella* spp. for the 2014/15 Financial Year (FY). The number of inpatients admitted to each specialty during this period were extracted from the hospital management information system and stratified by length of stay. The expected number of screening tests and inpatient days requiring contact precautions (including lag time for test results), were estimated for three iterative inclusion strategies. These were based on incorporating the highest ranking specialties sequentially: 1) circulation science and renal medicine only; 2) plus critical care, anaesthesia, neurology and neurosurgery, orthopaedic and reconstructive surgery; and 3) plus private patients. The potential fraction of the total CPE burden detectable through each strategy was estimated.

Result

Of the 99,105 inpatients recorded in the three hospitals in FY2014/15, strategies 1, 2 and 3 would have screened 4,371 (4.4%), 7,483 (7.6%) and 13,543 (13.7%). Assuming pre-emptive isolation of those undergoing screening was implemented, the requirement for contact precautions would require 22.3%, 40.6% and 60.6% of potential isolation bed days, respectively. Strategies 1, 2 and 3 would have had detected 17.1%, 27.8% and 47.5% of the total expected CPE burden. Marked variation in these variables was identified between hospitals.

Discussion

CPE screening is likely to generate considerable additional demand in terms of screening tests and patient isolation, especially if pre-emptive isolation is employed. We demonstrate that screening patients admitted to high risk specialties could identify up a high proportion of CPE likely to be present at the time of admission. However, a substantial number of CPE cases will occur outside these 'high risk' specialties. The development of screening strategies for CPE needs to balance risk and resource.

INTRODUCTION

Enterobacteriaceae are ubiquitous human commensals, yet also a frequent cause of hospital-acquired infections. Infections caused by *Escherichia coli* and *Klebsiella pneumoniae* are associated with urinary catheters,[1] ventilators,[2] and intravenous cannulae.[3] The rise in antimicrobial resistance among these organisms, has driven the use of alternative classes of antimicrobials, notably carbapenems.[4] In consequence, carbapenem-resistant Enterobacteriaceae and, within these, carbapenemase-producing Enterobacteriaceae (CPE), have emerged and spread.[5] While all carbapenem-resistant Enterobacteriaceae are of concern, CPE pose a significant public health threat due to the potential for rapid spread and ease of transmission of these resistance mechanisms[6] to other bacteria.

The emerging threat to global health from CPE has prompted several national[7-9] and international bodies[10] to develop screening guidelines.[11-12] The Public Health England (PHE) Toolkit was published in December 2013[13] and attempts to implement it have generated numerous questions.[14] There is limited data on the proportion of patients that are likely to be eligible for screening, the relative demand in tests and contact precautions that are likely to be generated, and the potential mismatch with available capacities.

This analysis proposes to address these questions by prioritizing the CPE screening to all the inpatients in specialties at higher risk for CPE. Risk factors for CPE include hospitalisation in intensive care and renal units.[15] Prioritising the CPE screening to high-risk specialties would be, compared with individual risk-factor based screening: (a) easier to administer, as it would be part of the admission protocols for all the patients admitted in these units; (b) potentially associated with higher impact, as these patients are more at risk of suffering from severe complications of CPE infections, and (c) cost-saving, if the screening successfully prevent outbreaks in these high-cost units.

The aim of this study is to estimate the demand for screening tests and burden of contact precautions on the available capacity.

METHODS

Setting

Three West London teaching hospitals were selected for this study. In FY2014/15, there were 32,884, 20,849 and 45,372 admissions in hospital A, B and C respectively. The number of single rooms with a toilet, which are suitable for isolation capacity, in hospital A, B and C were 114, 106 and 62 respectively.

Priority specialties

Data from Freeman *et.*[16] was used to rank the specialties to be prioritised by the CPE screening. The proportion of carbapenem-resistant *Klebsiella* spp. and *Escherichia coli* across the clinical specialities was: Circulation Science and Renal Medicine (cardiology, cardiothoracic surgery, renal transplant, renal dialysis, vascular surgery, rheumatology) 10.1%; Specialist Services (critical care, anaesthesia, neurology and neurosurgery, orthopaedic and reconstructive surgery) 8.8%; Private Patients 8.4%; Medicine (emergency, clinical pharmacology, endocrinology, gastroenterology, hepatology, genitourinary medicine, infectious diseases, medicine for the elderly, respiratory medicine and stroke medicine) 3.8%; Surgery and cancer (general surgery, breast surgery, endocrine surgery, hepatobiliary surgery, urology and oncology) 2.2%.

- Strategy 1 was screening all the inpatients in Circulation Science and Renal Medicine; Strategy 2 was Strategy 1 + Critical Care; Strategy 3 was Strategy 2 + Private Patients.

Demand

The laboratory demand is based on three consecutive negative tests at 0, 48 and 96 hours According to the PHE Toolkit, with positive results being followed up by one confirmatory test. However, not all inpatients

stay long enough to receive all three screens, so we modified our calculations to account for this using length of stay data for each specialty for FY2014/15. The patient management demand assumes that pre-emptive contact precautions are implemented, in a single room where possible. According to the PHE Toolkit,[13] each patient should be testedat 0, 48 and 96 hours.

Capacities

We have calculated the potential isolation bed day consumption comparing the number of bed days generated for the isolation of those undergoing CPE with the number of bed days avaiable in the hospitals (number of single rooms suitable for isolation x 365 days in a year). The assumption is that a hospital with a higher availability of potential isolation bed days is more able to respond to the extra demand in inpatient day equivalents in contact precautions required by the CPE screening.

Potential detection rate

It was assumed that sensitivity and specificity of the CPE tests were 100%. According to this rationale, the expected number of positive cases was equal to the number of inpatients in the specialties at risk multiplied by the proportion of carbapenem-resistant *Klebsiella* species and *Escherichia coli* by specialty according to Freeman *et al.* The expected number of carbapenem-resistant positive cases that were generated by each strategy was divided by the total expected cases in the whole hospital network. Although this detection rate is related to carbapenem-resistant bacteria, this should reflect the "potential" detection rate of CPE too, as CPE are a fraction of the carbapenem-resistant Enterobacteriaceae, assuming that the ratio of CRE:CPE is equal across the specialties.

RESULTS

Of the 99,105 admissions recorded in this network for FY2014/15, 4,371 (4.4%), 7,483 (7.6%) and 13,543 (13.7%) would have fallen under the Strategy 1, 2, and 3, respectively (Figure 1). The variation would have been higher across hospitals, with Strategy 3 (the most comprehensive) covering 4971 or 23.8% of total inpatients in hospital B, versus 5,871 or 12.9% in hospital C and 2,700 or 8.2% in hospital A.

Fig 1 Proportion of admissions falling under each strategy

The annual expected consumption of inpatient isolation days for contact precautions increased substantially between Strategy 1 and Strategy 3. For the whole network, Strategy 1 would have produced 14,551 contact precautions bed days between the first and third negative test and 8,400 contact precautions bed days between the expected positive tests and their discharge, for a total of 22,951 contact precautions bed days. Similarly, Strategies 2 and 3 would have generated a total of 41,775 and 62,388 contact precautions bed days.

For the network, the ratio of available isolation room bed days and contact precautions bed day requirements would increase from 22.3% to 60.6% between Strategy 1 and Strategy 3 (Figure 3). For individual hospitals, the lowest ratio would have been in hospital B, while it would have varied between less than 1% and 72.6% in hospital A and between 18.1% and 120.9% in hospital C. A *ratio* above 100% was a sign of excessive demand vs. the available capacity.

Fig 2 Inpatient day equivalents in contact precautions as % of potential isolation bed days

There was a substantial variation in potential detection rates of CPE. For the whole network, strategy 1, 2 and 3 would have potentially detected 17.1%, 27.8% and 47.5%. For hospitals, the detection rates would have had a much higher variation with the most comprehensive strategy 3 allowing to potentially detect 88.6% of the total expected CPE positive cases in Hospital B, versus 48.0% in hospital C and 27.3% in hospital A.

Fig 4 Detection rate by strategy

DISCUSSION

A threat to the implementation of the CPE screening could come from failing to keep up with the demand for tests and contact precautions. This study has used routinary available data to predict the impact of screening all the admissions in the high-risk specialties in FY2014/15. The most comprehensive Strategy 3 (screening all admissions to circulation scince and renal, critical care, and private patients) would have included a maximum of 13,543 or 13.7% of all inpatients in the hospital network. This coverage is likely to be easier to implement and more sustainable than individual risk-factor based screening of patients with a history of hospitalisation abroad on in high-risk NHS hospital, which according to a survey carried out by a West London hospital could include 20% of all inpatients.[18] We could not find other estimates on the expected demand that the inclusion criteria of the previous hospitalisation abroad on in high-risk hospitals would have generated. The main advantage of using the “specialty at risk“ approach was the possibility of using available hospital management data to compare the demand for testing and inpatient day equivalents in contact precautions with the available capacity. Furthermore, screening all inpatients in high-risk specialties would be administered through existing admission procedures.

The hospital network's capacity to detect most of the total CPE burden would have varied substantially across hospitals. Hospital A would have had the lowest proportion of admissions belonging to the target groups and thus the lowest fraction of the total expected positive cases. In other words, most of the CPE positive cases in this hospitals would have been occurred outside the target specialties at risk. This is due to the fact that although the prevalence was much lower in the specialties that were not included in the screening, the number of patients in these specilaties contributed to a substantial number of CPE cases. In contrast, hospital B would have had the highest proportion of admissions belonging to high- risk specialties and thus the highest potential detection rate. This shows that whatever inclusion criteria is adopted for screening, it is necessary to evaluate in each hospital the expected fraction of the total CPE burden that would be potentially detected.

Limitations

We have used proxies to assess the potential mismatch between incremental demand in contact precautions and available capacity. We have divided the total expected number of days incurred between consecutive tests by the total available physical isolation capacity in terms of single beds with toilet. Further research is needed to devise indicators to estimate the demand and capacity in staff time and supplies required to manage the screened cases. Our estimation of burden of contact precautions would be considerably lower if pre-emptive isolation was not performed.

Sensitivity and specificity were assumed to be 100%. Although this will not be the case, it is unlikely to affect the demand for tests and inpatient day equivalents in contact precautions estimated by this study. In fact, at the present low incidence rates of CPE, most of the demand will be generated by the negative cases undergoing three consecutive tests and contributing to most contact precautions bed days.

It has been assumed that the tests will be carried out at an interval of 48 hours between each other. This is based on the present guidelines and it does not take into account potential increase in the turnaround time that might be caused by excessive workload of the laboratory staff.

Implications of the results

The results show that targeting CPE screening in specialties at higher risk provides an evidence-based platform to match the demand in contact precautions with the available capacities. However, the efficiency of the inclusion criteria will depend on their ability to detect the highest potential fraction of the total CPE burden. Even if the target groups are selected according to their higher incidence rates, screening might fail to capture most of the potential CPE burden, especially if these target groups are relatively small in some of the hospitals.

Screening all the admissions to specialties at higher risk for CPE is likely to be simpler, compared with other inclusion criteria, and likely to prevent the worst consequences of CPE transmission. For example, with the PHE inclusion criteria, the admission staff will have to ask questions about previous hospitalisations in NHS high-risk hospitals, which is difficult to standardise. Instead, the existing administrative set up can be used to screen all the admissions and transfers to target specialties at risk and to extract the data to monitor the implementation of the screening. Furthermore, CPE associated mortality is highest in ICU and other specialties at risk and identifying carriers and infected patients before they enter these specialties would help to prevent transmission where it is most needed.

Conclusions

The study has provided a method to prioritise the screening, to estimate the expected number of tests and inpatient days equivalents of contact precautions and to compare demand with available capacity. This approach can provide a planning tool to identify the best alternatives in terms of inclusion criteria and sustainable demand for screening.

Next steps

The limitations of the study suggest the gaps still to be filled to estimate the cost-effectiveness of inclusion strategies for the CPE screening. These include the following:

- Estimation of CRE and CPE incidence rates for carriers and infected cases by specialty;
- Estimation of the transmission rates for carriers and infected cases;
- Standardized laboratory testing algorithm with a validation system to estimate sensitivity and specificity;
- Quantification of the relationship between number of CPE tests and turnaround times;
- Diagnostic costs per positive and negative case;
- Daily requirements in staff time and supplies to attend screened patients;

- Daily expected cost caused by the closure of high-risk specialties;
- Measures of effectiveness for CPE screening, such as the reduction of the CPE related blood stream infections.

The above-mentioned gaps require a more efficient use of hospital management information systems. There are several data systems including: (a) the patient administration systems, (b) laboratory information management systems, (c) pharmacy/dispensary/electronic prescribing systems, and (d) clinical notation systems. However, information is not always directly usable for extraction and analysis, and mechanisms to enable data warehousing and linkage are needed.[18]

Need a strong concluding paragraph – what are the take-home messages of the study?

CONTRIBUTORS

VV conceptualised the structure of the manuscript, reviewed the literature, wrote the 1st draft and managed the subsequent drafts. The other authors contributed with comments to the drafts and provided extra references.

CONFLICTS OF INTEREST

JAO is a consultant to Gama Healthcare. All other authors declare no conflicts of interest.

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