Understanding cost of care for patients on renal replacement therapy: looking beyond fixed tariffs

Running headline: Hospital costs for patients on RRT

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ABSTRACT

Background. In a number of countries, reimbursement to hospitals providing renal dialysis services is set according to a fixed tariff. While the cost of maintenance dialysis and transplant surgery are amenable to a system of fixed tariffs, patients with established renal failure commonly present with comorbid conditions that can lead to variations in the need for hospitalisation beyond the provision of renal replacement therapy.

Methods. Patient-level cost data for incident renal replacement therapy patients in England was obtained as a result of linkage of the Hospital Episodes Statistics dataset to UK Renal Registry data. Regression models were developed to explore variations in hospital costs in relation to treatment modality, number of years on treatment and factors such as age and comorbidities. The final models were then used to predict annual costs for patients with different sets of characteristics.

Results. Excluding the cost of renal replacement therapy itself, inpatient costs generally decreased with number of years on treatment for haemodialysis and transplant patients, whereas costs for patients receiving peritoneal dialysis remained constant. Diabetes was associated with higher mean annual costs for all patients irrespective of treatment modality and hospital setting. Age did not have a consistent effect on costs.

Conclusions. Combining predicted hospital costs with the fixed costs of renal replacement therapy showed that the total cost differential for a patient continuing on dialysis rather than receiving a transplant is considerable following the first year of renal replacement therapy, thus reinforcing the longer-term economic advantage of transplantation over dialysis for the health service.

Key words: comorbidities, dialysis, established renal failure, hospital costs, regression, transplantation

Short summary: In this paper, we analyse patient-level cost data for patients starting renal replacement therapy in England in order to explore how hospitals costs vary with treatment modality, number of years on treatment and factors such as age and comorbidities. The results of regression analyses suggest that, excluding the fixed costs of renal replacement therapy, inpatient costs generally decreased with number of years on treatment for haemodialysis and transplant patients, whereas costs for patients receiving peritoneal dialysis remained constant. Diabetes was associated with higher mean annual costs for all patients irrespective of treatment modality and hospital setting. Age did not have a consistent effect on costs.

INTRODUCTION

In an attempt to control rising costs, several countries have introduced a system of fixed reimbursement rates for the provision of chronic dialysis for patients with established renal failure (ERF) [1]. Since 2010, reimbursement to hospitals providing renal dialysis services in England has been set according to a national tariff under the Payment by Results (PbR) system [2]. There are plans to introduce a similar national tariff for kidney transplantation in the near future, with separate currencies being developed to capture three stages of the transplant pathway: preparation for transplant, the inpatient episode including the transplant procedure, and post-transplant outpatient activity [3].

While the annual cost of chronic maintenance dialysis and the cost of transplant surgery are amenable to fixed tariffs, patients with ERF commonly present with comorbidities such as diabetes, ischaemic heart disease and vascular disease, which can lead to variations in the use of healthcare resources beyond renal replacement therapy (RRT) itself [4]. A number of previous studies have explored hospitalisation rates or costs among dialysis patients, however, given the challenges of collecting patient-level resource use data, these studies have typically been restricted to a time horizon of one year or less [5-7].

Linkage of the Hospital Episodes Statistics (HES) dataset to UK Renal Registry (UKRR) data for patients who started RRT for ERF in England between 2003 and 2006 provides an opportunity to explore hospital inpatient and outpatient costs over a number of years among both dialysis and transplant patients. HES captures demographic information, comorbid conditions and data on all inpatient and outpatient care delivered in NHS hospitals in England, including treatment specialty and length of stay. The UKRR reports on the demography of incident RRT patients using data provided by renal centres. Linkage of these two datasets enhances the variables available for analysis and provides an opportunity to analyse a rich data source on hospitalisations for a cohort that represents >95% of all patients who started RRT during a defined period in England [8]. The aim of the current study is to analyse the linked dataset to explore variations in inpatient and outpatient hospital costs, separately

from the fixed cost of RRT, and in relation to treatment modality, number of years on treatment and factors such as age and comorbidities.

METHODS

The linked dataset comprised patients who started dialysis or received a kidney transplant in England between 1 April 2003 and 31 December 2006. The date of starting RRT was taken as the index date. If a patient on dialysis subsequently received a transplant, this patient then became part of the incident transplant cohort and the date of transplant was taken as the new index date for measuring subsequent hospitalisations. Comorbidity information in HES was determined from discharge codes from hospitalisations prior to starting RRT. Comorbidities were defined using International Classification of Disease version 10 (ICD10) codes applying algorithms previously described in the literature [9]. Inpatient costs were generated by grouping hospital episodes by Healthcare Resource Group (HRG) and applying the relevant 2011/12 PbR tariff associated with each HRG. Costs for outpatient appointments were assigned according to treatment function code [10]. Hospital episodes for the purpose of receiving maintenance dialysis or for undergoing transplant surgery were specifically excluded, but hospital episodes for any other reason, including procedures such as vascular access surgery, were included. This is because the aim of the present analysis is to explore variations in hospital costs separately from the costs associated with the fixed tariffs for dialysis and transplant surgery.

Linkage of the HES and UKRR datasets ended in December 2009 and therefore no further hospitalisation data were available beyond this point. Over the observation period, an increasing proportion of patients were therefore administratively censored part-way through a given year due to the end of data availability. The proportion of patients who were administratively censored ranged from 0% in year one to 47% in year six for haemodialysis patients, from 0% in year one to 38% in year six for peritoneal dialysis patients and from 11% in year one to 63% in year six for transplant patients. A comparison of patient characteristics and annual costs in the years prior to administrative censoring did not identify any systematic differences between those patients who had been censored

and those who had not. Therefore for the purposes of the current analysis, data from any year in which a patient was administratively censored were excluded under the assumption that these data were missing at random.

Patient characteristics and hospital costs in the first year after starting RRT are summarised by treatment modality using percentages and mean values as appropriate. Results of significance tests are presented to compare mean hospital costs between groups of patients with different characteristics of interest. Although cost data are typically not normally distributed, sample sizes in this dataset were sufficiently large for the use of t-tests or ANOVA to be robust to violations of the assumption of normality [11, 12]. In cases of unequal variances, Satterthwaite's approximation for standard errors was computed. To explore changes in hospital costs over time, mean annual costs and standard errors are presented by number of years on RRT.

Multiple regression was carried out to further determine which patient and treatment characteristics are important predictors of hospital costs. As cost data were positively skewed with a high proportion of patients with zero costs in the inpatient setting in any particular year, a two-part approach to the regression model was taken. Logistic regression was used to predict the probability of incurring any costs, followed by fitting generalised linear models to predict costs in patients who had at least one hospital episode in a given year. The effects of comorbidities on costs were explored using two approaches. In the first approach, individual comorbidities were included as covariates in the regression model and in the second approach, only the number of comorbidities was included as a covariate. Initially, all variables that were available in the dataset were included in the regression models and a process of backward elimination was used to inform variable selection using a P-value threshold of 0.2 [13]. Events such as transplant, renal recovery, death, or graft failure were included as covariates. In addition, a new variable was created to indicate if a patient died in the first half of the following year in order to adequately capture increased costs in the period prior to death.

All analyses were conducted in Stata (Version 13, Stata Corp, College Station, Texas, USA).

RESULTS

Descriptive analysis

Data on hospitalisations for 12 068 incident haemodialysis patients (Table 1a), 4 018 incident peritoneal dialysis patients (Table 1b) and 4 149 incident transplant patients (Table 1c) were available for analysis. The mean age for haemodialysis patients was 68.3 years compared with 56.0 years for peritoneal dialysis patients and 45.4 years for transplant patients. The two most common comorbidities were diabetes and hypertension and, of the nine comorbidities included in the scope of the analysis, the average number of comorbidities per patient at baseline was approximately 1.60 for haemodialysis patients, 1.26 for peritoneal dialysis patients and 1.56 for transplant patients.

Mean costs for patients during their first year of dialysis showed differences by modality, with haemodialysis patients incurring higher inpatient costs and peritoneal dialysis patients incurring higher outpatient costs. According to bivariate analysis, the presence of most comorbidities was associated with higher costs in the inpatient setting, but only diabetes was associated with significantly higher costs in both inpatient and outpatient settings and among both haemodialysis and peritoneal dialysis patients. Among transplant patients, congestive heart failure, peripheral vascular disease, diabetes and hypertension were all associated with higher costs in both inpatient and outpatient settings, whereas myocardial infarction, liver disease, cerebrovascular disease and deceased donor transplants were associated with higher costs only in the inpatient setting.

Table 2 summarises mean annual costs for patients receiving each type of RRT over the six years of available data. Combined inpatient and outpatient costs in the first year of RRT were similar for haemodialysis and transplant patients, however costs for transplant patients decreased more rapidly in subsequent years. Peritoneal dialysis patients had lower total hospital costs compared to haemodialysis patients in the first year, but higher average costs in year six.

Multiple regression

Bivariate analysis of year 1 costs (Tables 1a, 1b and 1c) showed that events such as death can have opposite effects on inpatient and outpatient costs. Therefore it was important to control for these in multiple regression analyses and to keep the development of models for inpatient and outpatient costs separate. Two-part regression models were developed to determine which patient and treatment characteristics are important predictors of hospital costs. The final two-part models for each treatment modality are provided as supplementary material (available online at http://ndt.oxfordjournals.org). Key findings can be summarised as follows:

In the inpatient setting, logistic regression results (Supplementary Table 1a) showed that the probability of incurring any inpatient costs generally decreased as the number of years on haemodialysis increased. Female gender and presence of comorbidities, with the exception of liver disease, increased the probability of incurring inpatient costs. The effect of comorbidities on the probability of incurring outpatient costs for haemodialysis patients was less consistent.

Compared to the first year on RRT, patients on peritoneal dialysis had a lower probability of incurring inpatient and outpatient costs in subsequent years (Supplementary Table 1b), however there was not a consistent trend in the probability of incurring costs over time as seen among haemodialysis patients.

For transplant patients, logistic regression results indicated that the probability of incurring inpatient costs, but not outpatient costs, generally decreased over time (Supplementary Table 1c). Female gender and comorbidities were again associated with a higher probability of incurring inpatient costs, whereas living donor transplants were associated with a lower probability of incurring inpatient costs compared to deceased donor transplants.

Following logistic regression, generalised linear models were fitted to model costs in the subset of patients who had at least one inpatient or outpatient episode in a given year (Supplementary Tables 2a, 2b and 2c). For haemodialysis and transplant patients, inpatient costs tended to decrease as number of years on RRT increased, however this pattern was not seen among peritoneal dialysis patients. Age did not have a consistent effect on costs across hospital settings and treatment

modalities, however where significant differences were noted, higher age was associated with lower costs. Of the comorbidities, only diabetes was consistently associated with higher mean annual costs for all patients irrespective of treatment modality and hospital setting.

Inpatient costs in the year of death were higher across all three RRT modalities, whereas outpatient costs in the year of death were lower. With the exception of the first year of the dataset, death events were fairly evenly distributed throughout the year, meaning that patients who died incurred significantly higher costs despite only being alive, on average, for approximately half of the year.

Alternative regression models based on the total number of comorbidities as a covariate, rather than on the presence or absence of individual comorbidities, yielded similar results, but were associated with slightly higher root-mean-square errors (RMSE). The number of comorbidities had a larger effect on hospital costs among transplant patients than among dialysis patients.

Application of regression models for predicting costs

A useful application of the regression models developed here is to predict hospital costs for patients with a given set of characteristics over time. Applying the models that have been developed, we can predict and compare costs for patients with different characteristics and by treatment modality. For illustrative purposes, Table 3 shows predicted inpatient and outpatient costs over a period of four years on each of the forms of RRT for three hypothetical patients: a 25-year-old female with no comorbidities, a 50-year-old male with diabetes and a 65-year-old male with peripheral vascular disease. Table 3 also shows the fixed costs associated with national tariffs for RRT (maintenance haemodialysis, peritoneal dialysis or deceased heart-beating donor transplant) [10, 14]. When comparing combined RRT and hospital costs over the four years among the three patients on the same modality, costs are similar on haemodialysis and transplant, however larger variations in costs are seen with peritoneal dialysis (range £101 938 to £109 213), mostly attributable to differences in inpatient costs. In all three patient examples, total costs are highest on haemodialysis and in each case, are approximately four times the total costs compared with a scenario in which each of these patients had received a transplant from a deceased donor.

DISCUSSION

Many health systems around the world are grappling with the need to contain the increasing costs of providing care for patients with ERF and in recent years this has led to the emergence of bundled payments or fixed tariffs for reimbursement to providers of dialysis services. Considerable attention has been focused on determining what costs should be included or excluded within a fixed rate of payment and there is variation between countries especially with respect to drug costs, laboratory tests and physician fees [1]. Less attention has been directed at characterising the magnitude of other hospital costs beyond the fixed tariffs for RRT that are incurred by patients with ERF. These costs can be considerable given the high rate of comorbidities among this patient population. Insight into variable hospital costs in addition to the fixed costs of RRT is important for having an overall understanding of the costs of managing ERF. Linkage of the United States Renal Data System (USRDS) and Medicare data allows for extensive analysis of costs in relation to patient characteristics and treatment factors, however such data sources outside the US are limited [15].

One-time linkage of the HES and UKRR datasets has provided a rare opportunity to analyse variations in hospital costs beyond RRT in a large cohort of patients with ERF in England and to explore changes in costs over several years, as well as in relation to treatment modality and comorbidities. As no attempt was made to distinguish renal-related resource use from non-renal-related resource use, the findings presented here are most relevant for looking at incremental costs between inpatient and outpatient settings, or between patients receiving different forms of RRT.

Excluding the fixed costs of RRT, our analysis showed that hospital costs were highest for all treatment modalities in the first year but hospital inpatient costs for both haemodialysis and transplant patients generally decreased with number of years on RRT, with transplant patients incurring lower annual costs than dialysis patients. A possible explanation for higher inpatient costs among incident haemodialysis patients could be access-related complications such as catheter-related infections, the need for catheter replacement or fistuloplasty and other forms of attention to dialysis access. In the UK, during the time period reflected in our analysis, a national audit showed that 69% of incident

haemodialysis patients commenced treatment using venous catheters [16]. For transplant patients, higher costs in the first year reflect the need for frequent monitoring in the post-operative phase to manage immunosuppression, including detection and management of complications such as new onset diabetes after transplant (NODAT) [17-19].

In the current analysis there was little evidence to suggest that hospital costs increased with age or number of years on RRT. In some cases, older age was in fact associated with lower costs. However, a pattern of increasing costs was seen with many comorbidities and it is plausible that the patients who remained alive for longer on RRT were on average healthier and required fewer hospitalisations. The possibility of unobserved confounding could not be ruled out, but we believe this highlights the importance of controlling for comorbidities when exploring the effect of age on costs in the ERF population. Outpatient costs for transplant patients were highest in the first year of RRT, but dropped considerably in subsequent years and fell below average outpatient costs for haemodialysis patients by year six. In comparison, hospital costs for patients on peritoneal dialysis remained relatively constant over time, except for a slight decrease in years 2 and 3. These findings challenge the commonly held assumption that costs increase with both age and time on RRT although caution should be exercised in extrapolating the findings beyond the 6-year period of our analysis. As with most retrospective datasets, there are several limitations to our analysis. In the HES dataset, coding practices meant that patients with missing comorbidity information could only be recorded as having no comorbidities, so the true extent of missing data was not known. However, the UKRR dataset also contained information on comorbidities at the start of RRT for approximately half of the patients in the sample. Where comorbidity data were available from both HES and UKRR data sources, concordance was 93% [8]. This high level of concordance between two independently collected data sources increases our confidence that missing data on comorbidities is unlikely to be a source of systematic bias in our analysis. Due to the structure of our dataset, another limitation is that we were unable to explore in more detail the specific reasons for variations in hospital costs as this would have required a more granular breakdown of admission codes and procedures. In addition, the current analysis did not take

into account drug costs, which fall outside both the fixed tariff for RRT and the hospital reimbursement codes in England.

Although differences in currency, reimbursement rates for RRT and the organisation of healthcare systems varies from country to country, a deeper understanding of the relationship between factors such as age, comorbidities, treatment modality and hospital costs is likely to cut across different countries with varied healthcare delivery paradigms. Looking beyond fixed tariffs for RRT, hospital costs make up approximately 20-25% of the overall cost of managing patients on chronic dialysis. Taking into account both the fixed costs of RRT and variations in hospital costs characterised in the current analysis, it is readily apparent that although the total costs of treating dialysis and transplant patients may be similar in the first year of RRT, the cost differential in subsequent years is considerable. This reinforces the longer-term economic advantage of transplantation over dialysis for the health service.

SUPPLEMENTARY DATA

Supplementary data have been submitted with this manuscript.

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CONFLICT OF INTEREST STATEMENT

None to declare.

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TABLES

Table 1a Haemodialysis patient characteristics and mean inpatient and outpatient costs (excluding the costs of maintenance dialysis) during the first year of renal replacement therapy

	n (%)	Mean inpatient cost (£) (95% CI)	p	Mean outpatient cost (£) (95% CI)	p
Age group					
<50 years	2 384 (19.8%)	7 452 (6 951 , 7 954)	0.319	1 342 (1 288 , 1 396)	<0.0005
50-64 years	2 900 (24.0%)	7 122 (6 667 , 7 577)		1 340 (1 291 , 1 389)	
65-75 years	3 911 (32.4%)	7 423 (7 032 , 7 815)		1 121 (1 079 , 1 163)	
>75 years	2 873 (23.8%)	6 934 (6 477 , 7 391)		893 (844 , 942)	
Gender					
Male	7 478 (62.0%)	7 084 (6 797 , 7370)	0.079	1 185 (1 153 , 1 216)	0.026
Female	4 590 (38.0%)	7 495 (7 140 , 7 850)		1 128 (1 090 , 1 165)	
Death					
No	9 530 (79.0%)	7 087 (6 821 , 7 354)	0.009	1 309 (1 280 , 1 337)	<0.0005*
Yes	2 538 (21.0%)	7 814 (7 467 , 8 160)		616 (578 , 655)	
Transplant					
No	11 644 (96.5%)	7 336 (7 106 , 7 566)	<0.0005*	1 169 (1 145 , 1 194)	0.009
Yes	424 (3.5%)	4 606 (4 110 , 5 103)		995 (858 , 1 131)	
Recovered renal function					
No	11 715 (97.1%)	7 270 (7 042 , 7 499)	0.127	1 178 (1 153 , 1 203)	<0.0005*
Yes	353 (2.9%)	6 241 (5 368 , 7 114)		664 (544 , 785)	
Myocardial infarction					
No	10 120 (85.1%)	7 185 (6 939 , 7 430)	0.033	1 183 (1 157 , 1 210)	0.019
Yes	1 774 (14.9%)	7 872 (7 302 , 8 443)		1 101 (1 041 , 1 162)	
Congestive heart failure					
No	9 630 (81.0%)	7 085 (6 827 , 7 344)	<0.0005*	1 187 (1 160 , 1 214)	0.010
Yes	2 264 (19.0%)	8 145 (7 707 , 8 585)		1 105 (1 050 , 1 160)	
Peripheral vascular disease					
No	10 285 (86.5%)	7 104 (6 859 , 7 349)	<0.0005*	1 170 (1 144 , 1 196)	0.854*
Yes	1 609 (13.5%)	8 459 (7 888 , 9 030)		1 177 (1 107 , 1 248)	
Cerebrovascular disease					
No	10 812 (90.9%)	7 241 (7 002 , 7 480)	0.205	1 180 (1 154 , 1 205)	0.034
Yes	1 082 (9.1)	7 749 (7 089 , 8 408)		1 087 (1011 , 1 164)	
Pulmonary disease					
No	10 293 (86.5%)	7 186 (6 937 , 7 435)	0.026	1 168 (1 142 , 1 194)	0.550*
Yes	1 601 (13.5%)	7 938 (7 434 , 8 443)		1 192 (1 118 , 1 265)	
Liver disease					
No	11 785 (99.1%)	7 260 (7 035 , 7 484)	0.143*	1 169 (1 145 , 1 194)	0. 180*
Yes	109 (0.9%)	10 263 (6 233 , 14 293)		1 379 (1 072 , 1 687)	
Diabetes					
No	7 846 (66.0%)	6 685 (6 415 , 6 956)	<0.0005*	1 081 (1 051 , 1 110)	<0.0005*
Yes	4 048 (34.0%)	8 454 (8 049 , 8 858)		1 346 (1 303 , 1 389)	
Cancer					
No	10 885 (91.5%)	7 248 (7 010 , 7 487)	0.266	1 167 (1 142 , 1 193)	0.311
Yes	1 009 (8.5%)	7 708 (7 045 , 8 370)		1 213 (1 119 , 1 307)	
Hypertension					
No	6 372 (53.6%)	7 525 (7 180 , 7 870)	0.024*	1 153 (1 122 , 1 184)	0.118
Yes	5 522 (46.4%)	7 013 (6 734 , 7 291)		1 192 (1 154 , 1 230)	

*Unequal variances

Table 1b Peritoneal dialysis patient characteristics and mean inpatient and outpatient costs (excluding the costs of maintenance dialysis) during the first year of renal replacement therapy

	n (%)	Mean inpatient cost (£) (95% CI)	p	Mean outpatient cost (£) (95% CI)	p
Age group					
<50 years	1 395 (34.7%)	4 874 (4 463 , 5 286)	0.003	1 712 (1 642 , 1 782)	<0.0005
50-64 years	1 217 (30.3%)	5 266 (4 825 , 5 707)		1 748 (1 674 , 1 823)	
65-75 years	967 (24.1%)	4 762 (4 267 , 5 257)		1 600 (1 516 , 1 684)	
>75 years	439 (10.9%)	6 321 (5 587 , 7 055)		1 320 (1 195 , 1 444)	
Gender					
Male	2 505 (62.3%)	5 200 (4 878 , 5 522)	0.428	1 647 (1 595 , 1 699)	0.696
Female	1 513 (37.7%)	4 998 (4 633 , 5 362)		1 664 (1 596 , 1 732)	
Death					
No	3 709 (92.3%)	4 755 (4 514 , 4 996)	<0.0005*	1 694 (1 651 , 1 738)	<0.0005
Yes	309 (7.7%)	9 553 (8 380 , 10 725)		1 158 (1 022 , 1 294)	
Transplant					
No	3 643 (90.7%)	5 275 (5 010 , 5 540)	<0.0005*	1 707 (1 663 , 1 751)	<0.0005*
Yes	375 (9.3%)	3 659 (3 316 , 4001)		1 130 (1 033 , 1 226)	
Recovered renal function					
No	3934 (97.9%)	5 158 (4 911 , 5 405)	0.060	1 673 (1 631 , 1 714)	<0.0005*
Yes	84 (2.1%)	3 528 (2 307 , 4 748)		745 (517 , 972)	
Myocardial infarction					
No	3 608 (90.8%)	5 057 (4 804 , 5 310)	0.021*	1 666 (1 622 , 1 710)	0.466
Yes	367 (9.2%)	6 191 (5 261 , 7 120)		1 613 (1 492 , 1 734)	
Congestive heart failure					
No	3 577 (90.0%)	4 963 (4 704 , 5 221)	<0.0005*	1 652 (1 609 , 1 695)	0.269*
Yes	398 (10.0%)	6 951 (6 202 , 7 670)		1 743 (1 587 , 1 899)	
Peripheral vascular disease					
No	3 656 (92.0%)	5 063 (4 806 , 5 320)	0.008	1 647 (1 604 , 1 689)	0.046*
Yes	319 (8.0%)	6 292 (5 500 , 7 084)		1 828 (1 655 , 2001)	
Cerebrovascular disease					
No	3 740 (94.1%)	5 043 (4 799 , 5 288)	0.006*	1 648 (1 605 , 1 690)	0.028*
Yes	235 (5.9%)	7 044 (5 631 , 8 458)		1 873 (1 677 , 2 070)	
Pulmonary disease					
No	3605 (90.7%)	5 026 (4 770 , 5 282)	0.001*	1 647 (1 604 , 1 691)	0.054*
Yes	370 (9.3%)	6 480 (5 641 , 7 319)		1 798 (1 651 , 1 945)	
Liver disease					
No	3 957 (99.6%)	5 152 (4 907 , 5 398)	0.275	1 661 (1 619 , 1 703)	0.794
Yes	18 (0.4%)	7 187 (3 361 , 10 743)		1 743 (812 , 2 674)	
Diabetes					
No	2 829 (71.2%)	4 492 (4 215 , 4 770)	<0.0005*	1 798 (1 453 , 1 543)	<0.0005*
Yes	1 146 (28.8%)	6 814 (6 321 , 7 307)		2 064 (1 976 , 2 152)	
Cancer					
No	3 810 (95.9%)	5 160 (4 907 , 5 413)	0.944	1 663 (1 621 , 1 706)	0.644
Yes	165 (4.1%)	5 204 (4 288 , 6 120)		1 614 (1 432 , 1 796)	
Hypertension					
No	1 986 (50.0%)	5 200 (4 840 , 5 561)	0.757	1 720 (1 659 , 1 782)	0.005*
Yes	1 989 (50.0%)	5 123 (4 790 , 5 456)		1 602 (1 546 , 1 658)	

*Unequal variances

Table 1c Transplant patient characteristics and mean inpatient and outpatient costs (excluding the costs of transplant surgery) during the first year of renal replacement therapy

	n (%)	Mean inpatient cost (£) (95% CI)	P	Mean outpatient cost (£) (95% CI)	P
Age group					
< 35 years	1 026 (25%)	3 941 (3 580 , 4 302)	<0.0005	4 111 (3 978 , 4 246)	0.914
36 - 45 years	1 110 (27%)	3 915 (3 568 , 4 263)		4 125 (3 996 , 4 254)	
46 - 55 years	973 (23%)	4 087 (3 716 , 4 458)		4 086 (3 948 , 4 224)	
> 55 years	1 040 (25%)	4 987 (4 628 , 5 346)		4 061 (3 928 , 4 195)	
Gender					
Male	2 589 (62.4%)	4 129 (3 908 , 4 350)	0.161*	4 073 (3 988 , 4 158)	0.373
Female	1 560 (37.6%)	4 400 (4 092 , 4 707)		4 136 (4 027 , 4 244)	
Donor type					
Deceased	2 660 (64.1%)	4 540 (4 306 , 4 774)	<0.0005*	4 095 (4 015 , 4 176)	0.131*
Living	1 367 (32.9%)	3 646 (3 373 , 3 919)		4 208 (4 086 , 4 331)	
Death					
No	4020 (96.9%)	4 160 (3 981 , 4 339)	0.004*	4 175 (4 108 , 4 241)	<0.0005
Yes	129 (3.1%)	6 424 (4 906 , 7 942)		1 657 (1 292 , 2 023)	
Graft failure					
No	3 874 (93%)	4 211 (4 027 , 4 395)	0.484*	4 279 (4 213 , 4 345)	<0.0005
Yes	275 (7%)	4 508 (3 695 , 5 321)		1 526 (1 294 , 1 758)	
Myocardial infarction					
No	3 758 (91.0%)	4 015 (3 834 , 4 195)	<0.0005*	4 110 (4 040 , 4 179)	0.637*
Yes	370 (9.0%)	6 666 (5 859 , 7 472)		4 170 (3 930 , 4 409)	
Congestive heart failure					
No	3 836 (93.9%)	4 051 (3 872 , 4 231)	<0.0005*	4 094 (4 026 , 4 163)	0.051*
Yes	292 (7.1%)	6 892 (5 952 , 7 832)		4 385 (4 101 , 4 669)	
Peripheral vascular disease					
No	3 625 (87.8%)	3 862 (3 683 , 4 040)	<0.0005*	4 070 (4 000 , 4 139)	0.001*
Yes	503 (12.2%)	7 067 (6 372 , 7 762)		4 443 (4 230 , 4 655)	
Cerebrovascular disease					
No	3 848 (93.2%)	4 082 (3 905 , 4 258)	<0.0005*	4 110 (4 041 , 4 179)	0.552
Yes	280 (6.8%)	6 597 (5 534 , 7 661)		4 190 (3 937 , 4 443)	
Pulmonary disease					
No	3 562 (86.3%)	4 194 (4 002 , 4 385)	0.112	4 114 (4 042 , 4 186)	0.962
Yes	566 (13.7%)	4 620 (4 087 , 5 153)		4 119 (3 946 , 4 292)	
Liver disease					
No	4 088 (99.0%)	4 220 (4 040 , 4400)	0.024*	4 115 (4 049 , 4 182)	0.919*
Yes	40 (1.0%)	7 530 (4 677 , 10 384)		4 068 (3 143 , 4 994)	
Diabetes					
No	3 002 (72.7%)	3 626 (3 439 , 3 813)	<0.0005*	3 963 (3 890 , 4 036)	<0.0005*
Yes	1 126 (27.3%)	5 921 (5 499 , 6 343)		4 520 (4 376 , 4 665)	
Cancer					
No	3 960 (95.9%)	4 255 (4 070 , 4441)	0.866	4 111 (4 043 , 4 179)	0.553
Yes	168 (4.1%)	4 176 (3 381 , 4 972)		4 213 (3 876 , 4 550)	
Hypertension					
No	1 003 (24.3%)	3 300 (3 021 , 3 579)	<0.0005*	3 845 (3 722 , 3 968)	<0.0005*
Yes	3 125 (75.7%)	4 558 (4 338 , 4 778)		4 202 (4 123 , 4 280)	

*Unequal variances

Table 2 Mean annual hospital costs by modality and number of years on renal replacement therapy (excluding the costs of maintenance dialysis and transplant surgery)

Haemodialysis patients				
Year	**n**	**Inpatient cost (£) Mean (SE)**	**Outpatient cost (£) Mean (SE)**	**Total inpatient and outpatient cost (£) Mean (SE)**
1	12,068	7 240 (114)	1 163 (12)	8 403 (116)
2	9,096	5 340 (95)	1 044 (13)	6 384 (98)
3	7,614	4 844 (93)	1 069 (15)	5 913 (96)
4	4,830	5 020 (105)	1 070 (20)	6 090 (111)
5	2,452	5 325 (169)	1 091 (27)	6 416 (176)
6	846	4 866 (231)	1 218 (62)	6 084 (248)
Peritoneal dialysis patients				
Year	**n**	**Inpatient cost (£) Mean (SE)**	**Outpatient cost (£) Mean (SE)**	**Total inpatient and outpatient cost (£) Mean (SE)**
1	4,018	5 124 (124)	1 653 (21)	6 777 (129)
2	2,897	4 140 (118)	1 407 (23)	5 547 (125)
3	1,934	4 198 (147)	1 514 (30)	5 712 (157)
4	1,000	4 830 (259)	1 541 (46)	6 371 (274)
5	440	4 433 (329)	1 510 (72)	5 943 (358)
6	137	4 859 (541)	1 484 (143)	6 343 (609)
Transplant patients				
Year	**n**	**Inpatient cost (£) Mean (SE)**	**Outpatient cost (£) Mean (SE)**	**Total inpatient and outpatient cost (£) Mean (SE)**
1	4 149	4 231 (92)	4 097 (34)	8 327 (106)
2	3 136	1 695 (77)	1 662 (21)	3 357 (88)
3	2 307	1 334 (65)	1 403 (22)	2 738 (77)
4	1 447	1 209 (77)	1 308 (27)	2 517 (91)
5	759	1 368 (130)	1 234 (36)	2 603 (148)
6	271	1 145 (205)	1 152 (53)	2 296 (225)

Table 3 Comparison of predicted inpatient and outpatient costs and renal replacement therapy costs by treatment modality over a four-year period for three hypothetical patients

Patient 1: 25-year-old female patient with no comorbidities

	Haemodialysis (HD)				Peritoneal dialysis (PD)				Transplant (TX)			
	Cost of HD (£)*	**Inpatient cost (£)**	**Outpatient cost (£)**	**Combined HD and hospital costs (£)**	**Cost of PD (£)***	**Inpatient cost (£)**	**Outpatient cost (£)**	**Combined PD and hospital costs (£)**	**Cost of TX surgery (£)***	**Inpatient cost (£)**	**Outpatient cost (£)**	**Combined TX and hospital costs (£)**
Year 1	24 804	6 204	1 295	32 303	20 440	4 250	1 745	26 435	14 832	3 452	4 019	22 302
Year 2	24 804	4 335	1 148	30 287	20 440	3 190	1 481	25 112	0	1 206	1 472	2 678
Year 3	24 804	3 750	1 162	29 716	20 440	3 223	1 626	25 289	0	995	1 228	2 223
Year 4	24 804	3 699	1 202	29 705	20 440	3 417	1 673	25 530	0	908	1 139	2 047
Total	99 216	17 989	4 807	**122 011**	81 760	14 080	6 526	**102 366**	14 832	6 561	7 858	**29 251**

Patient 2: 50-year-old male patient with diabetes

	Haemodialysis (HD)				Peritoneal dialysis (PD)				Transplant (TX)			
	Cost of HD (£)*	**Inpatient cost (£)**	**Outpatient cost (£)**	**Combined HD and hospital costs (£)**	**Cost of PD (£)***	**Inpatient cost (£)**	**Outpatient cost (£)**	**Combined PD and hospital costs (£)**	**Cost of TX surgery (£)***	**Inpatient cost (£)**	**Outpatient cost (£)**	**Combined TX and hospital costs (£)**
Year 1	24 804	6 739	1 504	33 047	20 440	5 677	2 140	28 257	14 832	3 637	4 319	22 788
Year 2	24 804	4 811	1 359	30 974	20 440	4 463	1 877	26 780	0	1 223	1 770	2 993
Year 3	24 804	4 197	1 379	30 380	20 440	4 501	2 022	26 963	0	1 013	1 526	2 539
Year 4	24 804	4 144	1 422	30 370	20 440	4 703	2 070	27 213	0	940	1 437	2 377
Total	99 216	19 891	5 664	**124 771**	81 760	19 344	8 109	**109 213**	14 832	6 813	9 052	**30 697**

Patient 3: 65-year-old male patient with peripheral vascular disease

	Haemodialysis (HD)				Peritoneal dialysis (PD)				Transplant (TX)			
	Cost of HD (£)*	**Inpatient cost (£)**	**Outpatient cost (£)**	**Combined HD and hospital costs (£)**	**Cost of PD (£)***	**Inpatient cost (£)**	**Outpatient cost (£)**	**Combined PD and hospital costs (£)**	**Cost of TX surgery (£)***	**Inpatient cost (£)**	**Outpatient cost (£)**	**Combined TX and hospital costs (£)**
Year 1	24 804	6 512	1 249	32 564	20 440	4 174	1 719	26 333	14 832	4 263	4 008	23 103

Year 2	24 804	4 627	1 104	30 535	20 440	3 113	1 454	25 007	0	1 498	1 461	2 959
Year 3	24 804	4 034	1 121	29 960	20 440	3 145	1 598	25 183	0	1 104	1 216	2 320
Year 4	24 804	3 980	1 163	29 947	20 440	3 330	1 645	25 415	0	1 045	1 127	2 172
Total	99 216	19 154	4 636	**123 006**	81 760	13 762	6 417	**101 938**	14 832	7 910	7 812	**30 554**

*Fixed costs for renal replacement therapy were estimated using the following assumptions and sources:

Haemodialysis: 2011-12 PbR tariff (HRG code LD06A = £159 per session) for satellite haemodialysis with access via arteriovenous fistula or graft 19 years and over = £159 x 3 times per week x 52 weeks = £ 24 804 per year

Peritoneal dialysis: 2011-12 PbR tariff (HRG code LD12A = £56 per day) for automated peritoneal dialysis 19 years and over = £56 x 365 days = £ 20 440 per year

Transplant surgery: NHS Reference Costs Spell Schedule 2011-12 (currency code LA02A) for kidney transplant, 19 years and over, from cadaver heart-beating donor = £ 14 832