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English Hospitals Can Improve Their Use of Resources: An Analysis of Costs and Length of Stay for Ten Treatments

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English hospitals can improve their use of resources: an analysis of costs and length of stay for ten treatments

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Glossary

ACS	Acute coronary syndrome
AHRQ	Agency for Healthcare Research and Quality
AMI	Acute myocardial infarction
C. difficile	Clostridium difficile
CABG	Coronary artery bypass graft
CHF	Congestive heart failure
DoH	Department of Health
DRG	Diagnosis related group
DV	Dummy variable
EP	Electrophysiology (test of electrical signals in the heart)
FCE	Finished consultant episode
HES	Hospital Episode Statistics
HRG	Healthcare Resource Group
ICD-10	International Classification of Diseases (10th revision)
ICH	Intra-cerebral haemorrhage
ICI	Ischemic cerebral infarction
ICU	Intensive care unit
LA	Laparoscopic appendectomy
LoS	Length of stay
MDC	Major Diagnostic Category
MFF	Market Forces Factor
NHS	National Health Service
OA	Open appendectomy
OECD	Organisation for Economic Co-operation and Development
PbR	Payment by Results
PCI	Percutaneous coronary intervention (angioplasty)
PSI	Patient Safety Indicator
PTCA	Percutaneous transluminal coronary angioplasty
RCT	Randomised controlled trial
RFA	Radiofrequency ablation (a treatment for heart rhythm problems)
SAH	Subarachnoid haemorrhage
SD	Standard deviation
SPARCS	Statewide Planning and Research Cooperative System
TEP	Total extraperitoneal (surgical approach for hernia)
TIA	Transient ischemic attack
UTI	Urinary tract infection

Abstract

Objectives

We investigate variations in costs and length of stay (LoS) among hospitals for ten clinical treatments to assess:

1. The extent to which resource use is driven by the characteristics of patients and of the type and quality of care they receive;
2. After taking these characteristics into account, the extent to which resource use is related to the hospital in which treatment takes place;
3. If conclusions are robust to whether resource use is described by costs or by LoS.

Data

We analysed patient-level data from the Hospital Episode Statistics (HES) data for 2007/8, which contains approximately 16.5 million inpatient records. This dataset was merged with costs derived from the Reference Cost database.

We extracted data on three medical 'conditions' (acute myocardial infarction (AMI); childbirth; stroke) and seven surgical treatments (appendectomy; breast cancer (mastectomy); coronary artery bypass graft (CABG); cholecystectomy; inguinal hernia; hip replacement; and knee replacement).

Methods

For each treatment, we used a two-stage approach to investigate variations in cost and LoS. In stage I, we ran fixed effects models to explore which patient-level factors explain variations. In stage II, we regressed the fixed effects from stage I against an array of hospital characteristics.

Results

The number of patients analysed ranged from 18,875 (CABG) to 549,036 (childbirth), and the number of hospitals ranged from 28 (CABG) to 151 (appendectomy, hernia and hip replacement).

Across the ten treatments, patient factors explained between 32% (stroke) and 72% (breast cancer and knee replacement) of the observed variation in costs. In the LoS analyses, the corresponding figures were 28% (stroke) and 63% (hip replacement). A higher number of diagnoses were consistently associated with higher cost and longer LoS. A higher number of procedures had a similar effect for 9 of the 10 treatments. The effects of age and gender were mixed, but higher levels of deprivation were associated with longer stays in 8 of the 10 treatments analysed. LoS was significantly longer for patients who were cared for by more than one hospital doctor, regardless of the treatment received. In the seven surgical interventions, wound infection was always associated with longer stays and usually with higher cost. Emergency admissions increased LoS for all conditions except stroke.

After accounting for these patient-level factors, substantial variation in costs and LoS among hospitals was evident for all ten treatments. These variations could not be explained by hospital characteristics such as size, teaching status, and the amount of the treatment in question that the hospital performed. We found that average hospital costs or LoS were correlated across similar types of treatments, notably hernia, cholecystectomy and appendectomy and hip and knee

replacement. A small number of hospitals had considerably lower average costs or LoS for most treatments; similarly some hospitals had considerably higher average costs or LoS.

Conclusion

The findings suggest that all hospitals have scope to make efficiency savings in at least one of the clinical areas considered by this study. A small number of hospitals have higher average costs or LoS across multiple treatments than their counterparts, and this cannot be explained by the characteristics of their patients or the quality of care. These hospitals are likely to struggle financially under Payment by Results (PbR) and need to consider how to improve their use of resources.

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Introduction

When comparing health care providers, variations in practice of any form are often cited as *prime facie* evidence of inefficiency or poor performance. If so, the reasoning goes, the overall efficiency of the health system would improve if all providers were able to meet the standards of the best. But seemingly sub-standard practice may not be indicative solely of inefficiency. There may be other influential factors that explain observed practice and it is, therefore, important to take these factors into account before drawing conclusions about relative efficiency. In this paper we set out and apply an empirical strategy to account for these factors when comparing costs and length of stay (LoS) across English hospitals.

We focus on ten different types of treatment using data from 2007/8. The analysis utilises Reference Cost data reported to the Department of Health (DoH) by English hospitals and recognises that variation in costs or LoS may be due to the different characteristics of patients receiving treatment in each hospital. We take this into account by applying a strategy adopted in other studies (Daidone and Street, 2011, Laudicella et al., 2010) to map each hospital's Reference Cost data to the Hospital Episode Statistics (HES) which contain detailed information about each patient treated in each hospital. This allows us to take patient characteristics into account and to compare hospital costs and LoS purged of the influence of these characteristics. Costs and LoS may be partly due to the characteristics of hospitals themselves and our comparisons also consider this possibility.

Objectives

This research investigates differences in resource use among patients for ten clinical treatments. We address three key questions:

1. To what extent is resource use driven by the characteristics of patients and of the type and quality of care they receive?
2. After taking these characteristics into account, to what extent is resource use related to the hospital in which treatment takes place?
3. Are conclusions robust to whether resource use is described by costs or by LoS?

Methods

Overview

We analysed patient-level data from the Hospital Episode Statistics (HES) data for 2007/8. We merged HES data with costs derived from the Reference Cost database. We extracted data on three medical 'conditions' (acute myocardial infarction (AMI); childbirth; stroke) and seven surgical treatments (appendectomy; breast cancer (mastectomy); coronary artery bypass graft (CABG); cholecystectomy; inguinal hernia repair; hip replacement; and knee replacement). For each treatment, we used a two-stage approach to investigate variations in resource use. In stage I, we ran fixed effects models to explore which patient-level factors drive variations in cost or LoS. In stage II, we regressed the fixed effects from stage I against an array of hospital characteristics.

Literature search

To provide a context for our findings we undertook a literature search on the MEDLINE database in order to identify relevant studies for the paper. We concentrated on papers from 1996 onwards that identified the drivers of cost and LoS for the ten treatments that we analyse. Search terms included type of condition, cost, length of stay, and patient characteristics including age, gender, socio-economic status, emergency cases, mortality, C difficile and urinary tract infection as well as some condition-specific characteristics.

	Defined by	ICD 10 WHO	OPCS 4.5 codes	Diagnosis	Exclude	Comments
Malignant growth						
Breast cancer	diagnosis + procedure	C50, D05	B27-B28	main	Age <1, outpatients (but include day cases), exclude males	
Cardiovascular diseases						
AMI	diagnosis	I21, I22	excl.: K40-K46	main	Age <1, outpatients (but include day cases)	Exclude bypass
Coronary artery bypass graft	procedure		K40-K46	all	Age <1, outpatients (but include day cases)	
Cerebrovascular diseases						
Stroke	diagnosis	I61, I63, I64		main	Age <1, outpatients and day cases	
Gastrointestinal diseases						
Inguinal hernia surgery	Procedure + diagnosis	K40	T20, T21	main	Age <1, outpatients (but include day cases)	
Appendectomy	Procedure + diagnosis	K35-K38	H01, H02 excl: H024	main	Age <1, outpatients (but include day cases)	
Cholecystectomy	Procedure + diagnosis	nts	J18	main	Age <1, outpatients (but include day cases)	Restrict definition to K80
Musculoskeletal disorders						
Hip-replacement	procedure		W37, W38, W39,W46, W47, W48, W93, W94, W95	all	Age <1, outpatients (but include day cases)	
Knee-replacement	procedure		W40,W41,W42	all	Age <1, outpatients (but include day cases)	
Pregnancy and birth						
Childbirth	diagnosis or procedure (see comment)	(Z37)	R17, R18, R19, R20, R21, R22, R23, R24, R25	secondary	Age <1, outpatients (but include day cases)	Aim to include all births using relevant diagnostic and/or procedure codes.

Figure 1: Definitions of the ten treatments analysed

Definition of treatments and sample

Figure 1 shows the ten treatments analysed, and the definitions and codes we used to identify eligible patients. We excluded patients treated in non-acute hospitals, those with missing cost data, cost 'outliers' (those with excessively high /low costs, defined as 3 standard deviations above or below the mean) and patients treated in hospitals that cared for fewer than 5 patients having the treatment in question. One hospital was excluded from the analyses because costs were reported only for elective patients.

Data sources

Our primary data source was the Hospital Episode Statistics for 2007/8, which contains around 16.5 million observations. Each observation comprises a Finished Consultant Episode (FCE, hereafter 'episode') which measures the time the patient spends under the care of a particular consultant. Around 10% of patients are cared for by more than one consultant, most usually because they are transferred from one specialty to another. We can track the episodes pertaining to each individual patient, allowing us to construct a provider spell for each patient, measuring the time from admission to discharge. By linking successive episodes for each patient, we can take account of diagnostic and other information in all of the records for those patients with multiple episodes.

Box 1: Mapping of Reference Cost to HES data

In their Reference Cost returns, hospitals report five pieces of cost information for each HRG (*h*=1…*H*) in each of their specialties (*j*=1…*J*):

- Average cost per day case in HRG *h*: c^d_{hjk}
- Average cost for elective patients in HRG *h* with a length of stay below the HRG-specific trimpoint value: c^e_{hjk}
- Excess *per diem* cost for an elective patient in HRG *h* who stays in hospital beyond the HRG-specific trimpoint: ex^e_{hjk}
- Average cost for non-elective (including maternity, baby or a transfer) patients in HRG *h* with a length of stay below HRG-specific trimpoint value: c^n_{hjk}
- Excess *per diem* cost for a non-elective patient in HRG *h* who stays in hospital beyond the HRG-specific trimpoint ex^n_{hjk}

Trimpoints are defined for length of stay outliers in each HRG according to whether the patient was admitted as an elective or non-elective. We define t^e_h as the elective trimpoint in days and t^n_h as the nonelective trimpoint for HRG *h*.

The costs provided by each hospital are assigned to each patient (*i=1…I*) recorded in HES, according to whether the patient was a day case (a^d), elective (a^e) or non-elective (a^n) admission and how long each patient stays in hospital, as follows:

- Day case: $if \quad a^d_{ihjk} \rightarrow c^d_{hjk}$
- Elective with length of stay at or below the elective trimpoint: $if\,(a^e_{ihj}, L_{ihj} \leq t^e_h) \rightarrow c^e_{hj}$
- Elective with length of stay above the elective trimpoint: $if\,(a^e_{ihjk}, L_{ihjk} > t^e_h) \rightarrow c^e_{hjk} + \left[ex^e_{hjk} \times (L_{ihjk} - t^e_h) \right]$
- Non-elective with length of stay at or below the non-elective trimpoint: $if\,(a^n_{ihjk}, L_{ihjk} \leq t_h) \rightarrow c^n_{hjk}$
- Non-elective with length of stay above the non-elective trimpoint: $if\,(a^e_{ihjk}, L_{ihjk} > t^n_h) \rightarrow c^n_{hjk} + \left[ex^n_{hjk} \times (L_{ihjk} - t^n_h) \right]$

Source: Daidone and Street, 2011

We assigned a cost to every patient recorded in HES by using the Reference Cost reported by all English hospitals. The mapping process is described in Box 1. This process is the same as that used in the analysis of the costs of specialist care which has informed PbR (Daidone and Street, 2011). Hospitals report their costs on the basis of episodes. For patients who have multiple episodes, we calculate the cost of their spell as the highest cost episode. We purged reported costs of the influence of geographical variation in input prices by dividing each patient cost by the relevant hospital-level Market Forces Factor (MFF) (Department of Health, 2010).

Concerns have been raised about the accuracy of Reference Costs and, hence, about the accuracy of patient-level costs assigned in this way. In view of these concerns, we also assessed whether results were robust to using LoS as a measure of resource use. LoS has the advantage that it is defined in a straightforward manner, calculated as the difference between the date of discharge and the date of admission. The disadvantage is that LoS is an imperfect indicator of resource use, particularly for surgical patients.

Analytic approach

Generally speaking, resource use varies among patients for two reasons: firstly because patients have (very) different characteristics in regard to demographics, diagnoses and treatment, and, secondly, because patients are treated in different hospitals. Our analysis is designed to identify the source of variation, and to establish the influence of particular patient and hospital characteristics on resource use. To do this, for each type of treatment we specified a multi-level model that recognises that patients (level 1) are clustered within hospitals (level 2). With only two levels to the hierarchy (patients clustered in hospitals), we can analyse variation in costs using a log-linear model with fixed effects[1]:

$$y_{ik}^{c} = \beta_0 + \boldsymbol{\beta}'\boldsymbol{x}_{ik} + \boldsymbol{\beta}''\boldsymbol{q}_{ik} + u_k + \varepsilon_{ik}$$

where $\boldsymbol{y_{ik}^{c}}$ is the (logarithmic) cost of patient *i* in hospital k, $x_{\boldsymbol{ik}}$ is a vector of characteristics of patient *i* in hospital *k* and $q_{\boldsymbol{ik}}$ is a vector capturing measures of quality. For characteristics that entered as dummy variables, their proportionate influence was calculated as $p = [\exp(\beta) - 1]$ (Halvorsen and Palmquist, 1980). We assessed the statistical significance of coefficients at the 0.1% level. The variables are summarised in Table 1. u_k captures the hospital influence on costs over and above the patient characteristics while ε_{ik} is the standard disturbance.

The fixed effects, u_k, can be interpreted as a measure of hospital performance, higher values implying that this hospital's costs are above average after taking into account the characteristics of the patients being treated (Hauck et al., 2003). However, the quality of care should be subject to hospital influence. As such, it would not be legitimate to control for quality when comparing costs or LoS *across* hospitals. Hence, the comparison of hospital costs was based on an equation that omits quality, namely:

$$y_{ik}^{c} = \beta_0 + \boldsymbol{\beta}'\boldsymbol{x}_{ik} + u_k + \varepsilon_{ik}$$

For each treatment type, we also estimated analogous models using LoS, y_{ik}^{s} , as the dependent variable. These are estimated as negative binomial (Negbin) models in recognition of the distributional nature of LoS. Full details of the models applied are provided in Street et al., (2012).

We then considered the estimated hospital effects, $\hat{u}_k$, from the cost and LoS analyses. This allowed us to explore reasons why some hospitals appear to have higher average costs or lengths of stay than others. We included hospital characteristics as a vector $\mathbf{z}_k$ of *m* variables in a regression of the form:

$$\hat{u}_k = \gamma_0 + \boldsymbol{\gamma}'\boldsymbol{z}_k + \varepsilon_k$$

We interpreted the hospital effects derived from the cost and LoS equations as measures of relative hospital performance (Laudicella et al., 2010). These capture the average cost or LoS of the hospital's patients, purged of the influence of the patient characteristics contained in the vector $\boldsymbol{x}$ in the first stage equations.

Visual comparison of the effects across hospitals is instructive. We created graphs in which hospitals were ordered (from left to right) from those with the lowest average effects to the highest. Patients

[1] If our interest were solely in costs, a random effects model would be preferable, as it would allow consideration of both patient-level and hospital-level characteristics in a single model. We adopted a fixed effects specification, though, in order to ensure comparability with the LoS equations. Given our sample sizes, in practice the fixed and random effects are virtually identical.

treated in hospitals to the left had lower costs or LoS than those in other hospitals (this not being due to the characteristics of their patients). These hospitals seemed to be making better use of resources than their counterparts.

Table 1: Variables used in the regression analyses

Type of variable	Definition of variable	Details
Stage 1		
xvars	Patient characteristics	• age categories (based on quintiles) • gender • socio-economic status • emergency admission dummy variable • transfer in dummy variable • transfer out dummy variable • total number of diagnoses • total number of procedures • One non-severe Charlson comorbidity • At least 1 severe or 2 non-severe Charlson comorbidities • diagnosis of hypertension • diagnosis of obesity • Healthcare Resource Groups (HRGs) • treatment type (diagnostic) variables • treatment type (procedural) variables • care by more than one consultant dummy variable (i.e. multiple episodes)
qvars	Quality variables	• death • at least one OECD surgical adverse event • diagnosis of urinary tract infection • wound infection • diagnosis of C. difficile
Stage 2		
zvars	Hospital variables	• Trust teaching status • Trust total volume of spells /1000 • Trust percentage of treatment cases • Trust weighted specialisation index • Hospital adverse event indicator 1: % cases wound infection /UTI • Hospital adverse event indicator 2: % cases surgical adverse event • Hospital adverse event indicator 3: % cases C. difficile • Hospital adverse event indicator 4: % deaths

We also summarise the relative performance of hospitals across the set of treatments they provide. This simply entails calculating their average rank across these treatments, after rescaling ranks to take account of the number of hospitals providing each type of treatment.

All econometric analyses were run using Stata 11.1 (STATA Corporation, College Station, TX).

Explanatory variables

Stage 1: Patient-level variables

Demographic variables

Resource use may be related to the socio-demographic characteristics of the patient. We constructed age categories based on quintiles chosen according to the observed distribution of age for the treatment type, with the second age category forming the reference group. A dummy variable was used to identify whether the patient was male. We also controlled for the income deprivation of each patient's local area, the rationale being that costs or LoS may be greater if timely discharge is more difficult to arrange in more deprived areas. The index of multiple deprivation score provides the proportion of the patient's local population living in households reliant on one or more means-tested benefits (Noble et al., 2004).

Admission and clinical variables

We considered the impact on resource use of whether the patient was admitted as an emergency, whether the patient was transferred from or to another institution or between consultants (i.e. had multiple episodes) as part of their care pathway.

We accounted for the number of different diagnoses and procedures performed and we specified various explanatory variables that are specific to the treatment in question which capture common diagnostic characteristics and procedural techniques.

We also applied a form of the Charlson index (Charlson et al., 1987, Quan et al., 2005). We first calculated a weighted global Charlson index score, by identifying the relevant ICD-10 codes recorded as secondary diagnoses and by overweighting the 6 most severe among the 17 dimensions of comorbidity proposed by Charlson.[2] This calculation is adapted when necessary, if the diagnoses included in the Charlson categories are directly related to the treatment analysed (in which case they are not comorbidities). The disregarded comorbidities are:

- "Myocardial infarction" for analysis of AMI and CABG
- "Cancer (any malignancy)" and "Metastatic solid tumor" for Breast cancer
- "Cerebrovascular disease" and "Hemiplegia/Paraplegia" for stroke

We then defined three distinct patient groups based on their Charlson score: a dummy variable for whether the patients suffer a single non-severe comorbidity (Charlson score=1); another dummy variable indicates the patient was diagnosed with at least one severe or two non-severe comorbidities (Charlson score>1); all other patients had no (Charlson) comorbidity (Charlson score=0).

HRGs

We accounted for the HRG to which patients are allocated. HRGs were identified as dummy variables when they included at least 1% of the sample for the treatment under consideration. These were ordered and labelled so that the first dummy variable was the HRG with the lowest PbR tariff (HRG1). As all patients were assigned to one HRG or another, in all specifications we omitted the HRG to which the largest proportion of patients were allocated. This means that coefficients for all variables can be interpreted in relation to this omitted reference HRG. A residual dummy variable captured all other patients that were not assigned to the identified HRGs. There is substantial variation in the number of HRG variables in the models depending on the type of treatment under consideration: from 2 for stroke to 14 for hip replacement.

Quality variables

We also included a set of variables to capture the quality of care, the first of which indicates whether the patient died in hospital.

Patient safety is a critical component of health care quality. The Agency for Healthcare Research and Quality (AHRQ) and the University of California-Stanford Evidence-based practice Center developed Patient Safety Indicators (PSIs) for use with hospital administrative data (Drösler et al., 2009, Quan et

[2] The "Hemiplegia/Paraplegia", "Renal disease" and "Cancer (any malignancy)" comorbidities are weighted by a coefficient 2, cases of "Moderate or severe liver diseases" by a coefficient 3, and "Metastatic solid tumor" and the "AIDS/HIV" cases by a coefficient 6 (see Charlson et al., 1987 for details).

al., 2008). We used the PSI 5 (Foreign body left in during procedure), 7 (Infection and inflammatory reaction due to other vascular device, implant, etc), 12 (Pulmonary embolism/Deep vein thrombosis), 13 (Sepsis) and 15 (Accidental cut, puncture, perforation, or haemorrhage during medical care) and collapsed these into one dummy variable indicating the presence of an adverse event. For childbirth, we used PSI 18 (Obstetric trauma) rather than the other indicators.

Finally, we defined three dummy variables that also can be considered measures of quality, namely when urinary tract infection (UTI: ICD-10 codes N30.x, N39.0, O23.x and O86.2), post-operative surgical infection (T81.4) or C. difficile (A047) are suffered during hospitalisation. Such events are a sign of poor quality and might increase the cost and the duration of the hospital stay.

All of these quality variables are omitted from the model which is used for the analysis of the hospital fixed effects because it is generally accepted that quality is within the hospital's control.

Stage 2: Hospital-level variables

Costs and LoS may vary among patients not merely because of their characteristics but also because of the hospital in which they are treated. Our second-stage analysis is designed to explore the explanatory power of various hospital characteristics, incorporated in the vector $\mathbf{z}_k$.

The characteristics considered include the hospital's teaching status; the amount and range of activity undertaken; and the quality of care.

Teaching hospitals were identified using data from the Compendium of Clinical and Health Indicators (The NHS Information Centre, 2009), which assigns hospitals to 'clusters' including an 'acute teaching' cluster.

Hospitals might benefit from economies of scale, experiencing decreasing average costs as volume increases. To examine this we included the number of patients (in thousands) treated in the hospital and the proportion (in percent) of these having the treatment under consideration.

The range of activity offered by the hospital may also influence costs, and again it is difficult to predict the direction of influence. We adapted a general definition of specialisation that describes the concentration of activity across Major Diagnostic Categories (MDCs) in each hospital (Daidone and D'Amico, 2009). As the HES data do not include MDCs, we used the HRG4 chapter to which patients were assigned (A, B, C etc). The index ranges between 0 (the hospital's workload by HRG chapter is distributed identically to that of the national average) and 1 (when all of a hospital's activity is confined to a single HRG chapter).

Another reason that costs may differ among hospitals is that the quality of care differs. We considered four adverse events indicators, estimated as the proportion of patients receiving a treatment who experienced the adverse event. Indicator 1 is the rate of those experiencing either a wound infection or UTI (or both). Indicator 2 is the rate of patients experiencing a PSI adverse event; for childbirth, we use obstetric adverse events as a rate of those having childbirth. Indicator 3 is the rate of patients with C. difficile, and indicator 4 is the death rate.

Table 2: Overview of the ten treatment types

Treatment type	AMI	Appendectomy	Breast cancer	CABG	Child birth	Cholecystectomy	Hernia (inguinal)	Hips	Knees	Stroke
N (patients)	72,807	32,927	30,025	18,875	549,036	43,917	64,155	82,902	62,034	69,372
N (hospitals)	150	151	139	28	144	148	151	151	147	149
No. HRG DVs	7	3	7	4	7	6	4	14	4	2
Length of stay (Los): mean (sd)	7.6 (9.0)	3.5 (3.0)	2.8 (2.7)	12.5 (11.1)	2.4 (2.2)	2.3 (3.8)	0.7 (1.7)	12.3 (14.2)	6.9 (5.7)	20.2 (24.4)
Log of cost: mean (sd)	7.4 (0.6)	7.6 (0.4)	7.5 (0.5)	8.9 (0.4)	7.3 (0.5)	7.5 (0.5)	7.0 (0.5)	8.6 (0.4)	8.3 (0.4)	7.8 (0.7)
Adjusted cost (£): mean (sd)	£1,885 (£1,253)	£2,221 (£914)	£2,083 (£948)	£7,658 (£2,616)	£1,611 (£727)	£1,971 (£936)	£1,221 (£549)	£5,499 (£1,884)	£4,452 (£1,801)	£3,002 (£2,125)
Correlation: log of cost and LoS	0.25*	0.24*	0.50*	0.12*	0.43*	0.41*	0.35*	0.29*	0.10*	0.39*
Patient characteristics										
age: mean (sd)	70.0 (14.1)	28.6 (17.2)	60.5 (12.6)	67.1 (9.8)	28.9 (6.1)	51.2 (16.2)	58.2 (18.1)	73.2 (12.2)	69.6 (9.5)	75.1 (13.6)
total no. diagnoses / patient: mean (sd)	5.1 (2.8)	1.7 (1.3)	2.3 (1.5)	6.6 (3.3)	3.2 (1.4)	2.3 (1.7)	1.9 (1.4)	4.1 (2.8)	3.1 (2.0)	5.7 (3.3)
total no. procedures / patient: mean (sd)	1.2 (1.6)	1.5 (1.0)	3.4 (1.1)	3.7 (2.3)	2.4 (1.2)	2.3 (0.9)	2.3 (0.7)	2.6 (1.2)	2.4 (0.9)	2.1 (1.7)
% males (n)	63.3% (46,107)	55.6% (18,304)	0.0% (0)	78.7% (14,848)	0.0% (0)	23.5% (10,303)	92.5% (59,322)	33.9% (28,074)	42.1% (26,129)	47.5% (32,982)
socioeconomic status (% living in area of income deprivation) (n)	16.3% (11,872)	16.1% (5,310)	14.2% (4,265)	15.3% (2,896)	19.3% (106,135)	16.4% (7,224)	14.7% (9,416)	14.0% (11,572)	14.6% (9,036)	16.2% (11,236)
% emergency admission (n)	87.3% (63,585)	97.7% (32,157)	0.3% (91)	10.7% (2,017)	0.4% (2,455)	9.7% (4,262)	4.2% (2,704)	36.7% (30,440)	0.8% (508)	95.5% (66,250)
% transferred in from other institution (n)	16.8% (12,226)	4.1% (1,348)	0.2% (59)	25.3% (4,781)	0.7% (3,819)	0.6% (248)	0.3% (202)	3.2% (2,629)	0.4% (247)	8.4% (5,843)
% transferred out to other institution (n)	21.1% (15,379)	0.4% (136)	0.4% (113)	7.2% (1,364)	0.6% (3,171)	0.3% (149)	0.3% (166)	11.0% (9,143)	2.4% (1,489)	19.7% (13,647)
% with one non-severe Charlson comorbidity (n)	27.4% (19,974)	7.6% (2,491)	11.4% (3,427)	29.5% (5,561)	3.2% (17,800)	13.5% (5,931)	10.5% (6,764)	22.0% (18,267)	20.1% (12,439)	27.2% (18,864)
% with >= 1 severe / 2 non-severe Charlson comorbidities (n)	20.9% (15,227)	0.9% (280)	1.7% (509)	16.7% (3,155)	0.1% (455)	2.4% (1,068)	2.7% (1,743)	10.0% (8,319)	5.0% (3,071)	16.6% (11,519)
% with hypertension (n)	39.8% (28,994)	3.5% (1,158)	19.7% (5,925)	60.4% (11,396)	0.0% (132)	16.6% (7,296)	16.3% (10,471)	37.3% (30,889)	41.8% (25,908)	47.7% (33,063)
% obese (n)	1.8%	0.4%	0.7%	4.3%	0.6%	2.2%	0.2%	1.4%	2.5%	0.7%

Treatment type	AMI	Appendectomy	Breast cancer	CABG	Child birth	Cholecystectomy	Hernia (inguinal)	Hips	Knees	Stroke
	(1,287)	(128)	(208)	(805)	(3,399)	(967)	(150)	(1,164)	(1,566)	(469)
% treated by more than one consultant within stay (n)	47.1%	11.4%	0.8%	22.6%	4.3%	4.9%	1.2%	14.0%	3.0%	63.8%
	(34,313)	(3,740)	(244)	(4,259)	(23,663)	(2,136)	(780)	(11,641)	(1,842)	(44,270)
% deaths (n)	10.1%	0.1%	0.0%	2.5%	0.0%	0.1%	0.1%	3.4%	0.2%	24.0%
	(7,381)	(42)	(7)	(481)	(10)	(43)	(58)	(2,778)	(135)	(16,678)
% with at least one OECD adverse event (n) **	1.4%	0.6%	0.1%	2.0%	2.0%	0.9%	0.1%	1.2%	0.9%	3.1%
	(1,046)	(183)	(26)	(382)	(11,078)	(380)	(79)	(1,001)	(547)	(2,170)
% with urinary tract infection (n)	3.4%	0.5%	0.2%	1.3%	0.7%	0.2%	0.1%	3.6%	0.6%	9.0%
	(2,457)	(163)	(61)	(242)	(3,805)	(95)	(61)	(2,953)	(347)	(6,251)
% with wound (post-op) infection (n)	0.1%	1.3%	0.2%	2.8%	0.0%	0.3%	0.0%	0.9%	0.2%	0.2%
	(62)	(439)	(67)	(535)	(13)	(132)	(32)	(786)	(155)	(108)
% with C. difficile (n)	0.5%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.7%	0.1%	1.8%
	(339)	(15)	(4)	(77)	(17)	(20)	(9)	(606)	(43)	(1,262)
Hospital characteristics										
% teaching hospitals	14.7%	14.6%	13.7%	64.3%	13.9%	14.9%	14.6%	14.6%	12.9%	14.8%
Total mean no. inpatients /yr ('000)	85.24	84.08	85.10	122.48	84.44	85.27	84.02	84.61	83.78	85.66
% treatment group cases	0.7%	0.3%	0.3%	1.2%	5.3%	0.4%	0.6%	0.9%	0.7%	0.6%
Hospital specialisation status (Gini index) ***	0.18	0.18	0.17	0.24	0.17	0.17	0.18	0.19	0.19	0.17
Hospital adverse event indicators										
1: % cases w wound infection or UTI	4.0%	2.0%	0.6%	3.7%	0.7%	0.5%	0.1%	4.8%	0.9%	9.2%
2: % cases with OECD adverse event *	2.9%	1.7%	0.5%	2.6%	2.0%	0.5%	0.1%	3.7%	0.8%	5.6%
3: % cases with C. difficile	0.7%	0.1%	0.0%	0.4%	0.0%	0.1%	0.0%	0.8%	0.1%	1.9%
4: % deaths	11.2%	0.1%	0.0%	3.0%	0.0%	0.1%	0.1%	3.8%	0.3%	23.7%

Note: All LoS analyses were run using a negative binomial model because of the overdispersion in the dependent variable.
* Significant at 0.1% level
** in childbirth, an obstetrics adverse event variable was substituted in the first and second stage regressions.
***the Gini index is a continuous variable and ranges from 0 (non-specialised hospital) to 1 (fully specialised hospital).
Source: Hospital Episode Statistics 2007/8; Reference Costs 2007/8.
Abbreviations: DV: dummy variable; UTI: urinary tract infection; sd: standard deviation

Results

Descriptive overview

We analysed patients admitted to hospital for one of ten types of treatment, summarised in Table 2. The number of patients in each treatment group ranged from 18,875 (CABG) to 549,036 (childbirth), and the number of hospitals contributing data ranged from 28 (also for CABG) to 151 (for appendectomy, hernia and hip replacement).

CABG patients had the highest mean cost (£7,658), reflecting the complexity of their care. These patients also had the highest mean number of diagnoses (6.6) and procedures (3.7) and were most likely to have been transferred in from another institution (25.3%). CABG patients also had high levels of comorbidity: almost 30% had one non-severe Charlson comorbidity, 17% had one severe (or at least two non-severe) Charlson comorbidities (in addition to AMI), and over 60% had hypertension. CABG patients were the most likely group of patients to suffer a post-operative wound infection (2.8% on average).

Stroke patients had the longest stays (20.2 days) and were, on average, also the oldest patients in our analysis (mean age: 75). They were also the most likely type of patient to have multiple consultants overseeing their care (63.8% saw at least two consultants), most likely to die (24.0%), or to suffer an adverse event (3.1%), urinary tract infection (UTI) (9.0%), or to contract C difficile (1.8%).

Patients undergoing an operation for inguinal hernia had both the lowest average LoS (0.73 days) and lowest average cost (£1,221).

Women who had come to hospital to give birth had the lowest rates of comorbidity (both for non-severe and severe Charlson categories, and for hypertension) and were the group of patients least likely to die during their stay (0.002%) or to suffer wound infection (0.002%) or C difficile (0.003%). The lowest rate of adverse events was among Breast Cancer and Hernia patients (0.1%).

Appendectomy patients were the youngest group (aged 28.6 on average) and were also the most likely to be admitted as emergencies (97.7%). Women with breast cancer were the least likely to be treated as emergency cases (0.3%) and also were the least likely to be transferred between specialties during their hospital stay (0.8%).

When the characteristics of the hospitals are compared, some striking differences are apparent. Although CABG patients were treated in a relatively small number of hospitals (28), most (64.3%) of these were teaching hospitals. These were also the most specialised hospitals, with a mean specialisation index of 0.24. For the remaining types of treatment, the index ranged between 0.17 and 0.19.

Regression results

The patient-level analyses explained between 32% (stroke) and 72% (breast cancer and knee replacement) of the variation in cost. When LoS was the dependent variable, the corresponding figures were 28% (stroke) and 63% (hip replacement).

Looking across the ten treatment types, a number of patterns are evident:

- **Age**: in general, older age was associated with higher cost and longer LoS.
- **Gender**: females were more costly and had longer stays than males, although the effect was not always statistically significant.

- **Socioeconomic status**: patients from more deprived areas sometimes had higher costs and more frequently had longer stays.
- **Transfers**: patients who were transferred in to hospital were often costlier cases, but the impact of transfers out on resource use was mixed.
- **Total diagnoses**: a higher total number of recorded diagnoses was associated with higher cost and longer stay. This finding was consistent across all ten treatments.
- **Total procedures**: a higher total number of recorded operations was associated with higher cost in most cases (9/10 treatments) and always with longer stay.
- **Multiple episodes**: the impact on cost was variable, but patients cared for by more than one consultant typically had significantly longer stays.
- **Quality**: in most treatments, adverse events drove up LoS. Similarly where significant, costs were higher.

Few of the hospital variables we tested proved to be significant explanators of cost or LoS. When holding patient characteristics constant, the following hospital-level factors were found to be significant:

- Hospital specialisation was a significant explanator for variations in the cost of appendectomy. The more specialised the hospital – the fewer different types of activity undertaken – the higher the average cost.
- The relative volume of hernia cases undertaken explained variations in stay. In hospitals that undertook a larger proportion of hernia cases, average stay was significantly shorter.
- The higher the mortality rate amongst stroke patients, the longer was average LoS.

In none of the other seven treatments analysed was any hospital characteristic statistically significant in explaining average cost or LoS.

The literature review identified a number of papers that analysed the predictors of cost and LoS for each condition. These included randomised controlled trials, systematic reviews, and studies using administrative patient data. Papers using bivariate and multivariate regression models with cost and LoS as the variable of interest were especially relevant. Most of the studies identified age and gender as being important drivers of variation in cost and LoS. Studies of appendectomy and inguinal hernia in particular tended to focus on the differences in terms of cost and LoS between open and laparoscopic approaches. Several studies found a positive relationship between the number of diagnoses and procedures performed and cost and/or LoS. Similarly the number of complications and poorer quality were generally found to be positively related to costs or LoS.

Table 3: Overview of stage 1 (patient-level) regression results

Explanatory variable	AMI		APPEND -ECTOMY		BREAST CANCER		CHILDBIRTH		CHOLE-CYSTECTOMY		CABG		HERNIA		HIP REPLACEMENT		KNEE REPLACEMENT		STROKE	
	Cost	LoS	Cost	LoS	Cost	LoS	Cost	LoS	Cost	LoS	Cost	LoS	Cost	LoS	Cost	LoS	Cost	LoS	Cost	LoS
Age	+/ns	-/+	+/ns	+/ns	+/ns	+/ns	+/ns	+/ns	+/ns	-/+	ns	-/+	+/-	+/-	+/ns	-/+	+/ns	-/+	+/-	+/-
Gender	ns	-	ns	-	NA	NA	NA	NA	ns	ns	ns	-	-	-	ns	-	ns	-	ns	-
Socioeconomic status	ns	+	ns	ns	ns	+	+	+	+	+	ns	+	+	+	ns	+	ns	+	ns	ns
Emergency admission DV	+	+	+	+	ns	+	+	+	+	+	ns	+	+	+	+	+	ns	+	ns	-
Transfer-in DV	+	ns	+	+	ns	ns	+	+	ns	ns	+	+	ns	+	-	ns	ns	+	+	+
Transfer-out DV	-	ns	ns	ns	ns	+	-	-	ns	+	+	+	ns	+	+	+	+	+	+	+
Total number diagnoses	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Total number procedures	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	ns	+	+	+
1 non-severe Charlson comorbidity	ns	+	ns	-	ns	ns	-	-	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	-
At least 1 severe / 2 non-severe Charlson comorbidities	ns	+	ns	ns	ns	ns	ns	+	ns	ns	ns	+	ns	ns	ns	ns	ns	ns	-	-
Hypertension comorbidity DV	-	-	ns	ns	ns	-	ns	ns	ns	ns	-	-	-	-	-	-	ns	-	ns	-
Obesity comorbidity DV	-	-	ns	ns	ns	ns	ns	-	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
HRGs	+/ns	-/ns	-/+	+/ns	+/-	+/ns	+	+	+/ns	+/ns	-/+/ns	-/+/ns	-/+	-/+	-/+/ns	-/+	+/-	+/-/ns	-/ns	ns
Treatment specific variables	-/+/ns	-/ns	-	+/ns	-/+/ns	-/+/ns	+/ns	+/-	+/-	+/-	ns	-/+/ns	-/+/ns	-/+/ns	+/-	+/ns	+/ns	+/ns	+/-	+/-/ns
Multiple episode DV	+	+	-	+	ns	+	+	+	ns	+	-	+	+	+	-	+	ns	+	+	+
Mortality DV	-	-	ns	ns	ns	ns	ns	ns	ns	ns	ns	-	ns	ns	ns	-	ns	ns	-	-
Adverse event DV	+	+	ns	ns	ns	ns	+	+	ns	ns	+	+	ns	ns	ns	+	ns	+	+	+
Infection: UTI	+	+	ns	ns	ns	+	ns	+	ns	ns	ns	+	ns	ns	+	+	ns	+	+	+
Wound infection	ns	+	+	+	+	+	ns	ns	ns	+	+	+	ns	+	+	+	ns	+	ns	ns
C. difficile	+	+	ns	+	ns	ns	ns	+	ns	ns	ns	+	ns	ns	+	+	ns	+	+	+
N	72793	72793	32927	32927	30025	30025	549036	549036	43917	43917	18875	18875	64155	64155	82902	82902	62034	62034	69372	69372
r2_a / adjusted deviance r^2	0.412	0.424	0.632	0.394	0.722	0.391	0.547	0.339	0.626	0.544	0.517	0.570	0.574	0.410	0.501	0.625	0.718	0.408	0.318	0.279

Key: DV: dummy variable; HRG: Healthcare Resource Group; UTI: urinary tract infection; ns: not significant; NA: not applicable.

Note: results are based on those from the *full* models; significance assessed at the 0.1% level (***)

Acute Myocardial Infarction (AMI)

Literature review

- Our searches found three studies looking at the drivers of cost among AMI patients.
- Bramkamp et al., (2007) used Switzerland's national multicenter registry, which included a representative sample of 65 hospitals and 11,625 patient records, to investigate inpatient costs of acute coronary syndromes (ACS).
    - Their multivariate linear regression model found that older patients (>65) were more costly than those under 65.
    - They also found that the cost of treating female patients was 5% higher than male patients.
- Dormont and Milcent, (2004) used data from 1994-1997 that included a sample of 7,314 patients in 36 public hospitals to investigate the drivers of hospital costs for AMI in France.
    - The authors used natural costs as the dependent variable and conditioned on LoS by including it as an explanatory variable in their analysis.
    - They found that males were more costly than females and that cost was a decreasing function of age. While this result may seem counterintuitive, the authors suggest this is probably due to older people having undergone fewer procedures.
- As part of the EuroDRG project, researchers from 10 countries sought to explain the determinants of cost and LoS across Europe using individual level data from their country (Peltola et al., 2012).
    - In 7/10 countries, older patients had longer lengths of stay or higher costs.
    - A higher number of diagnoses significantly increased both cost and LoS.
    - More procedures and the use of PTCA (Percutaneous transluminal coronary angioplasty) or stent significantly increased cost in most countries.
    - Mortality was associated with significantly lower cost or LoS in almost all countries.

Patient-level analysis

Results of our analysis of the costs and LoS for the 72,807 patients treated in 150 hospitals for AMI are presented in Table 4. The table reports summary statistics followed by four sets of regression results. For the first two sets, costs are the dependent variable, the full model including all patient-level variables and the partial model omitting measures of quality. The second two sets of results analyse LoS as the dependent variable. In Box 2 below, we highlight those variables that are significant (P<0.001) explanators of cost or LoS.

Box 2: Variables that are significant explanators of cost or LOS for AMI

Variables	Our Findings
Dependent variables (mean)	Cost – £1,885 LoS – 7.6
Demographics	Cost and LoS generally increased with patient age. LoS was also longer among female patients and patients living in poorer areas.
Admission/ Discharge	Emergency admissions were 7% more costly and LoS is 37% longer than electives. Patients transferred in had 13% higher costs while patients transferred out were 6% cheaper. The impact of transfers on patient LoS was insignificant when quality indicators were included. When quality was excluded, patients transferred in had 7% shorter spells while those transferred out stayed 6% longer. Patients treated by more than one consultant had significantly longer LoS and higher costs.
Case Complexity	Patients undergoing more procedures or with more diagnoses had higher costs and LoS. LoS was also higher among patients diagnosed with Charlson comorbidities, by 5% for non-severe comorbidities and 13% for major comorbidities. However, a diagnosis of hypertension or obesity was associated with 4% lower cost and shorter LoS for hypertension (13%) and obesity (9%).
HRGs	Relative to the base HRG case "actual or suspected AMI" (EB10Z), costs were highest, increasing by 45%-60%, when revascularisation procedures involved stenting (EA31Z, EA32Z and EA33Z). The broader "Other non-complex cardiac surgery with catheterisation" (EA41Z) was associated with 19% higher costs, while catheterisation used alone in patients under 19 (EA36Z) cost 41% more than the reference group. The use of catheterisation and stents generally reduced patient LoS.
Treatment Specific	Patients diagnosed with a subsequent AMI had a 3% lower cost and 9% shorter LoS. A small proportion of patients were treated with stents (15%) or a PTCA procedure (1%). These patients had 24% shorter and 22% shorter LoS respectively. However, where a PTCA procedure was used, costs were 13% higher. The shorter LoS of these patients who were given a stent or PTCA may in part be due to their levels of comorbidity, which were significantly lower than those of other patients (Figure 2). ST elevated AMI cases had lower cost and LoS while non ST elevated cases had higher cost and LoS. However, the impact of these variables was only significant when no adjustment was made for the quality of patient care.
Quality	Patients who experienced an adverse event, or infection, had longer LoS and higher costs. Around 10% of patients died whilst in hospital. These patients had 19% lower costs and 34% shorter LoS.

Table 4: Cost and LoS in AMI: patient-level analysis

Explanatory variable	mean	sd	Log of cost				LoS #			
			Full Model		*Partial Model*		*Full Model*		*Partial Model*	
			β	se	β	se	β	se	β	se
Age 1: <59	0.224	0.417	-0.015**	0.005	-0.013**	0.005	0.887***	0.008	0.887***	0.008
Age 2: 59-69	0.227	0.419	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Age 3: 70-77	0.196	0.397	0.022***	0.005	0.017**	0.005	1.141***	0.011	1.142***	0.012
Age 4: 78-84	0.188	0.391	0.052***	0.005	0.045***	0.006	1.272***	0.013	1.277***	0.013
Age 5: 85+	0.165	0.371	0.099***	0.006	0.083***	0.007	1.497***	0.018	1.497***	0.018
Gender	0.633	0.482	-0.005	0.004	-0.008*	0.004	0.957***	0.007	0.944***	0.007
Socioeconomic status	0.163	0.122	0.018	0.015	0.021	0.016	1.135***	0.034	1.166***	0.036
Emergency admission DV	0.873	0.333	0.064***	0.011	0.098***	0.011	1.367***	0.027	1.478***	0.03
Transfer-in DV	0.168	0.374	0.125***	0.01	0.101***	0.01	0.984	0.017	0.927***	0.016
Transfer-out DV	0.211	0.408	-0.062***	0.005	-0.051***	0.005	1.016	0.01	1.057***	0.011
Total number diagnoses	5.124	2.829	0.029***	0.001	0.037***	0.001	1.095***	0.002	1.117***	0.002
Total number procedures	1.181	1.582	0.052***	0.002	0.060***	0.002	1.148***	0.004	1.156***	0.004
One non-severe Charlson comorbidity	0.274	0.446	0.001	0.004	-0.012**	0.004	1.049***	0.009	1.023**	0.008
At least 1 severe or 2 non-severe Charlson comorbidities	0.209	0.407	0.013*	0.006	-0.016**	0.006	1.125***	0.012	1.065***	0.012
Hypertension comorbidity DV	0.398	0.490	-0.036***	0.004	-0.036***	0.004	0.872***	0.006	0.860***	0.006
Obesity comorbidity DV	0.018	0.132	-0.037***	0.011	-0.036**	0.011	0.913***	0.021	0.907***	0.02
HRG1: EB10Z DV; Actual or Suspected MI	0.677	0.468	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
HRG2: AB06Z DV; Minor pain procedures	0.031	0.174	-0.007	0.013	-0.044**	0.014	0.919***	0.015	0.849***	0.015
HRG3: EA36Z DV; Catheter 19 Years+	0.094	0.292	0.344***	0.007	0.359***	0.007	0.968*	0.013	1.001	0.013
HRG4: EA41Z DV; Other non-complex Cardiac Surgery with Catheterisation	0.020	0.140	0.177***	0.015	0.171***	0.016	0.777***	0.022	0.778***	0.021
HRG5: EA31Z DV; PCI with 0-2 Stents	0.103	0.304	0.369***	0.015	0.399***	0.009	0.939**	0.023	0.719***	0.011
HRG6: EA32Z DV; PCI with 0-2 stents and Catheterisation	0.031	0.173	0.439***	0.016	0.443***	0.012	0.875***	0.025	0.651***	0.015
HRG7: EA33Z DV; PCI 3 with Stents	0.011	0.103	0.470***	0.02	0.494***	0.017	0.990	0.036	0.764***	0.025
HRG8: Other non-reference HRG DV	0.033	0.180	0.315***	0.016	0.274***	0.017	0.909***	0.019	0.829***	0.019
ST elevated MI	0.296	0.456	-0.007	0.005	-0.019***	0.005	0.978**	0.008	0.949***	0.008
Non-ST-elevated	0.114	0.318	0.014*	0.007	0.035***	0.007	1.031*	0.013	1.051***	0.014
Subsequent MI	0.177	0.382	-0.028***	0.005	-0.027***	0.005	0.910***	0.009	0.897***	0.008
Insertion of Stent into Coronary Artery	0.155	0.362	0.032*	0.014			0.765***	0.018		
PTCA in Episode DV	0.010	0.100	0.126***	0.024			0.782***	0.03		
Multiple episode DV	0.471	0.499	0.186***	0.004			1.511***	0.012		
Mortality DV	0.101	0.302	-0.216***	0.008			0.658***	0.01		
Adverse event DV	0.014	0.119	0.097***	0.018			1.318***	0.037		
Infection DV: UTI	0.034	0.181	0.145***	0.011			1.406***	0.027		
Infection DV: post-operative infection	0.001	0.029	0.201**	0.068			1.456***	0.164		
Infection DV: C difficile	0.005	0.068	0.466***	0.037			2.331***	0.102		
Constant			6.891***	0.013	6.906***	0.013	2.153***	0.052	2.271***	0.055
alpha							0.386***	0.004	0.443***	0.004
N			72793		72793		72793		72793	
r2_a / adjusted deviance r^2			0.447		0.412		0.479		0.424	

Exponentiated coefficients; DV: dummy variable; HRG; healthcare resource group; PCI: Percutaneous coronary intervention; UTI: urinary tract infection. * p < 0.05, ** p < 0.01, *** p < 0.001

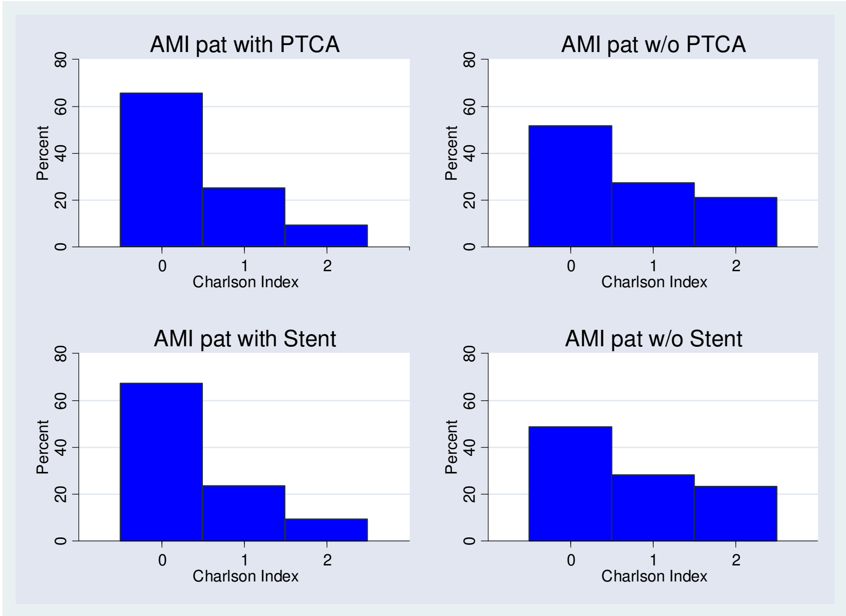

Figure 2: Relationship between comorbidity (Charlson score), PTCA and Stenting: AMI patients

Note: the figures compare the levels of comorbidity in treated and untreated patients. Comorbidity is assessed using the Charlson index: this is scaled as 0 (no Charlson comorbidity), 1 (one non-severe Charlson comorbidity), or 2 (at least one severe, or more than one non-severe, Charlson comorbidity). Only 1% of the 72,793 patients with AMI (n=735) received a PTCA, and 15% (11,270) received a stent. For both stents and PTCAs, patients who did not receive the procedure were sicker than those who were treated.

Hospital performance

Care for AMI patients in England was provided in 150 hospitals. Figure 3 plots the hospital fixed effects from the cost and LoS equations, once the differences in patient characteristics (other than quality) are controlled for. Hospitals are ranked by their deviation from the average (national) cost or LoS. Hospitals on the left hand-side have lower costs (LoS) than the average, while those on the right hand-side have higher costs (LoS). We see that, even after controlling for measurable characteristics of patients, large variations in the average cost or LoS of AMI patients across hospitals persisted. Average costs varied from 16% below to 10% above the national average while average LoS varied from 54% below to 57% above the national average. However we did not identify any specific characteristics of hospitals that had a significant influence on their average costs or LoS.

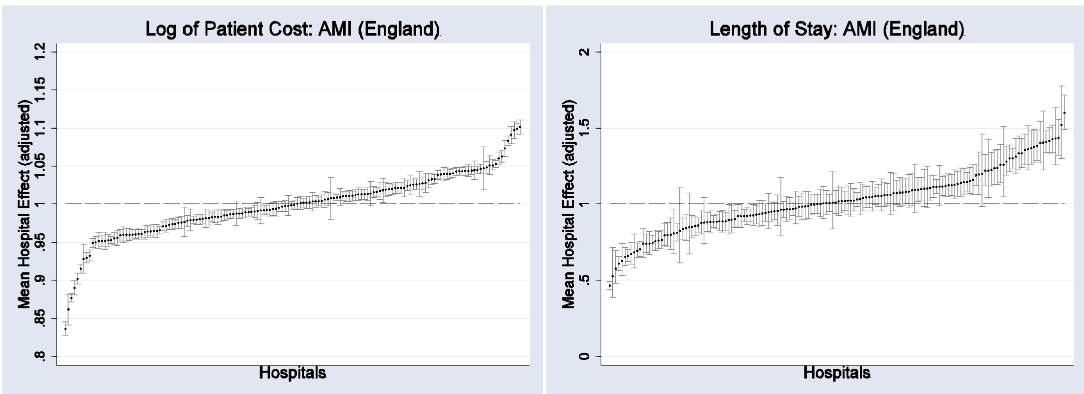

Figure 3: Hospital fixed effects: AMI

Hospitals at both extremes of the two distributions are identified below. Judgements about the relative performance of some hospitals depend on whether costs or LoS are examined. For instance, AMI patients treated at the Royal Brompton & Harefield NHS Trust and The Cardiothoracic Centre - Liverpool NHS Trust had the lowest LoS nationally but this did not translate directly into lower costs.

In other hospitals, both the average cost and LoS were among the lowest nationally, notably Worthing & Southlands Hospitals NHS Trust, George Eliot Hospital NHS Trust, and North Hampshire Hospitals NHS Trust. At the other extreme, some hospitals had both high costs and LoS, namely Royal United Hospital Bath NHS Trust, Swindon & Marlborough NHS Trust, and Trafford Healthcare NHS Trust.

Overall, the rank correlation between each hospital's average cost and LoS was r=0.25 (P=0.0017) indicating a small, but significant, positive relationship between hospital average cost and LoS for AMI.

Box 3: Hospitals in top/bottom 5% by rank: AMI

cost rank	LoS rank	Hospital Name
1	50	Southend University Hospital NHS Foundation Trust
2	48	Salisbury NHS Foundation Trust
3	18	North Cheshire Hospitals NHS Trust
4	6	Worthing & Southlands Hospitals NHS Trust
5	8	George Eliot Hospital NHS Trust
6	93	South Warwickshire General Hospitals NHS Trust
7	4	North Hampshire Hospitals NHS Trust
8	102	Lancashire Teaching Hospitals NHS Foundation Trust
143	15	Bradford Teaching Hospitals NHS Foundation Trust
144	144	Swindon & Marlborough NHS Trust
145	140	Royal United Hospital Bath NHS Trust
146	113	Wrightington, Wigan & Leigh NHS Trust
147	98	Heatherwood & Wexham Park Hospitals NHS Trust
148	133	West Middlesex University Hospital NHS Trust
149	11	Royal Devon & Exeter NHS Foundation Trust
150	25	Southampton University Hospitals NHS Trust

LoS rank	cost rank	Hospital Name
1	55	Royal Brompton & Harefield NHS Trust
2	138	The Cardiothoracic Centre - Liverpool NHS Trust
3	29	Papworth Hospital NHS Foundation Trust
4	7	North Hampshire Hospitals NHS Trust
5	65	University College London Hospitals NHS Foundation Trust
6	4	Worthing & Southlands Hospitals NHS Trust
7	101	Ealing Hospital NHS Trust
8	5	George Eliot Hospital NHS Trust
143	96	Surrey & Sussex Healthcare NHS Trust
144	144	Swindon & Marlborough NHS Trust
145	82	City Hospitals Sunderland NHS Foundation Trust
146	136	Mid Yorkshire Hospitals NHS Trust
147	140	Trafford Healthcare NHS Trust
148	94	Essex Rivers Healthcare NHS Trust
149	93	Tameside & Glossop Acute Services NHS Trust
150	44	Weston Area Health NHS Trust

Appendectomy

Literature review

- Much other research has concentrated on determining the cost and LoS impact of laparoscopic appendectomy (LA) relative to open appendectomy (OA).
- Sporn et al., (2009) performed a retrospective analysis of data from an annual survey of U.S. community based hospitals for the years 2000 to 2005.
  - Patients were stratified into those with complicated appendectomy and those without.
  - After controlling for age, gender, ethnicity and a number of comorbidities, LoS for LA was found to be 15% shorter than OA in both complicated and uncomplicated cases.
  - Costs for LA were 22% higher in uncomplicated cases and 9% higher for complicated cases.
- Sauerland et al., (2010) conducted a Cochrane systematic review of the diagnostic and therapeutic effects of LA and OA.
  - Sixty seven studies were included of which 56 compared LA to OA in adults. They found that length of hospital stay was shorter for those undergoing LA by 1.1 day.
- Tsai et al., (2008) used a retrospective study to analyse diabetic and non-diabetic patients who acquired acute appendicitis in a single institution over a 5 year period.
  - Those diagnosed with diabetes had a longer hospital stay compared to non-diabetic patients.
- As part of the EuroDRG project, researchers analysed cost and LoS for the treatment of appendectomy across 10 European countries (Mason et al., 2012).
  - They found a U-shaped relationship between age and LoS with younger (<11) and older (>35) age groups tending to have longer stays.
  - A higher number of diagnosis and procedures significantly increased costs and LoS.
  - Where significant, emergency cases tended to have longer stays and higher costs.

Patient-level analysis

Full results of our analysis of the costs and LoS for the 32,927 patients treated in 151 hospitals for appendectomy are presented in Table 5. Following the summary statistics, we estimate from the analyses of cost and LoS applying both the full and partial models. Variables that are significant (P<0.001) explanators of cost or LoS are summarised in Box 4 below.

Box 4: Variables that are significant explanators of cost or LOS for Appendectomy

Variables	Our Findings
Dependent variables (mean)	Cost – £2,221 LoS – 3.5
Demographics	Patients aged 14 and under had significantly higher costs and longer LoS than those aged 15 to 20. LoS was longer among patients over 29 and in female patients.
Admission/ Discharge	Patients transferred in from another hospital and emergency cases had higher costs and longer LoS (see Figure 4). Emergency patients had 42% higher costs and 79% longer LoS, suggesting a marked difference to the 2% of elective appendectomy patients. Patients transferred between consultants stayed 10% longer but cost 2% less than those under the care of a single consultant throughout their hospital stay.
Case Complexity	Patients diagnosed with a larger number of conditions had higher cost and LoS. Cases involving more procedures were also associated with higher cost and LoS. However, patients diagnosed with a single, non-severe, Charlson comorbidity had 7% shorter LoS.
HRGs	Relative to the reference HRG of “Appendectomy in over 18s without complications” (FZ20B), patients aged under 18 (FZ20C) had 8% lower costs. Of adult patients, those who suffered from complications (FZ20A) had 30% higher costs and 23% longer LoS compared with the reference group.
Treatment Specific	Patients who underwent a laparoscopic procedure had lower costs, even if this approach failed. If a laparoscopic procedure was successful, patient LoS was 23% shorter.
Quality	Patients who suffered from a post operative infection had 13% higher costs and 46% longer LoS, while LoS was over twice as long in the small proportion (<0.1%) of cases with C. difficile.

Table 5: Cost and LoS in appendectomy: patient-level analysis

Explanatory variable	mean	sd	Log of cost				LoS #			
			Full Model		*Partial Model*		*Full Model*		*Partial Model*	
			β	se	β	se	β	se	β	se
Age 1: 1 to 14	0.219	0.414	0.022***	0.005	0.028***	0.005	1.122***	0.013	1.162***	0.013
Age 2: 15 to 20	0.197	0.398	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Age 3: 21 to 29	0.199	0.399	-0.018**	0.005	-0.019***	0.006	0.994	0.015	0.992	0.015
Age 4: 30 to 43	0.192	0.394	-0.012*	0.006	-0.013*	0.006	1.082***	0.016	1.086***	0.017
Age 5: 44+	0.193	0.395	0.005	0.006	0.007	0.006	1.331***	0.021	1.363***	0.022
Gender	0.556	0.497	-0.002	0.003	0.004	0.003	0.932***	0.007	0.967***	0.007
Socioeconomic status	0.161	0.124	-0.009	0.012	-0.01	0.012	1.066*	0.032	1.067*	0.033
Emergency admission DV	0.977	0.151	0.350***	0.02	0.356***	0.02	1.787***	0.061	1.905***	0.067
Transfer-in DV	0.041	0.198	0.095***	0.012	0.096***	0.012	1.130***	0.025	1.140***	0.026
Transfer-out DV	0.004	0.064	0.048	0.034	0.05	0.034	1.251*	0.11	1.248**	0.105
Total number diagnoses	1.688	1.264	0.015***	0.002	0.018***	0.002	1.103***	0.005	1.132***	0.005
Total number procedures	1.547	0.994	0.025***	0.003	0.020***	0.002	1.145***	0.006	1.122***	0.005
One non-severe Charlson comorbidity	0.076	0.264	-0.015*	0.006	-0.019***	0.006	0.932***	0.014	0.898***	0.014
At least 1 severe or 2 non-severe Charlson comorbidities	0.009	0.092	-0.014	0.02	-0.025	0.02	0.891*	0.044	0.823***	0.04
Hypertension comorbidity DV	0.035	0.184	-0.003	0.009	-0.008	0.009	1.018	0.025	0.982	0.024
Obesity comorbidity	0.004	0.062	-0.005	0.022	-0.006	0.022	0.895*	0.049	0.871*	0.048
HRG1: FZ20B DV; appendectomy >18 w/o mcc	0.579	0.494	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
HRG2: FZ20C DV; appendectomy <18	0.349	0.477	-0.073***	0.006	-0.072***	0.006	1.003	0.016	1.01	0.016
HRG3: FZ20A DV; appendectomy >18 w mcc	0.040	0.196	0.262***	0.011	0.289***	0.01	1.233***	0.029	1.360***	0.03
HRG4: Other non-reference HRG DV	0.032	0.175	0.286***	0.018	0.298***	0.018	1.222***	0.029	1.347***	0.032
Laparoscopy DV	0.239	0.426	-0.039***	0.004			0.773***	0.008		
Failed laparoscopy DV	0.033	0.178	-0.029***	0.008			1.048**	0.019		
Multiple episode DV	0.114	0.317	-0.025***	0.005			1.096***	0.014		
Mortality DV	0.001	0.036	0.009	0.048			0.789	0.099		
Adverse event DV	0.006	0.074	0.071*	0.03			1.108*	0.054		
Infection DV: UTI	0.005	0.070	0.026	0.02			1.102	0.07		
Infection DV: post-operative infection	0.013	0.115	0.119***	0.019			1.460***	0.043		
Infection DV: C difficile	0.000	0.021	0.217*	0.105			2.518***	0.395		
Constant			7.239***	0.021	7.218***	0.021	1.228***	0.046	1.056	0.041
alpha							0.063***	0.004	0.073***	0.004
N			32927		32927		32927		32927	
r2_a / adjusted deviance r^2			0.635		0.632		0.423		0.394	

Exponentiated coefficients; DV: dummy variable; w: with; w/o: without; cc: complications and comorbidities; icc: intermediate cc; mcc: major cc; UTI: urinary tract infection.
* p < 0.05, ** p < 0.01, *** p < 0.001

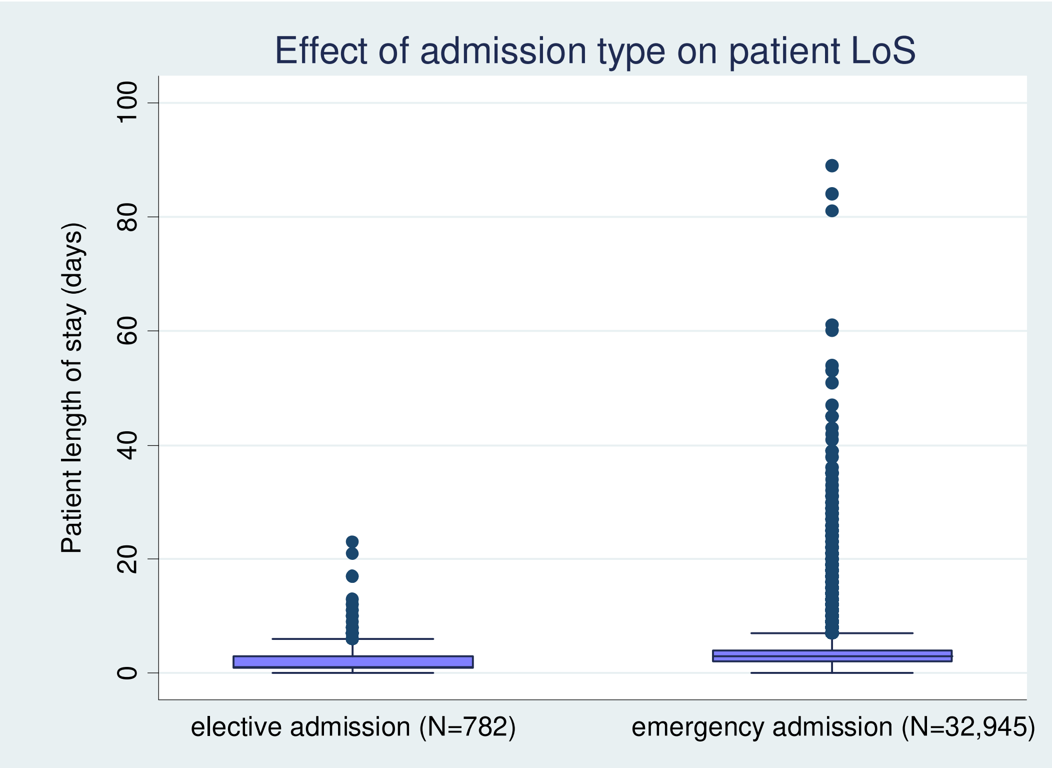

Figure 4: Variation in LoS by admission type: appendectomy

Note: Box plot shows, from top to bottom: outside values (dots), upper adjacent value, 75th percentile (upper hinge), median, 25th percentile (lower hinge) and lower adjacent value.

Hospital performance

After adjusting for casemix differences, the variation in average hospital costs for appendectomy was not substantial, ranging from 11% below to 11% above the national average. In contrast, the average LoS varied from 40% below to 49% above the national average. In the stage 2 analysis, we found that the more the hospital concentrates on a limited range of activities, the higher the average costs of treating appendectomy patients. No other variable was significant.

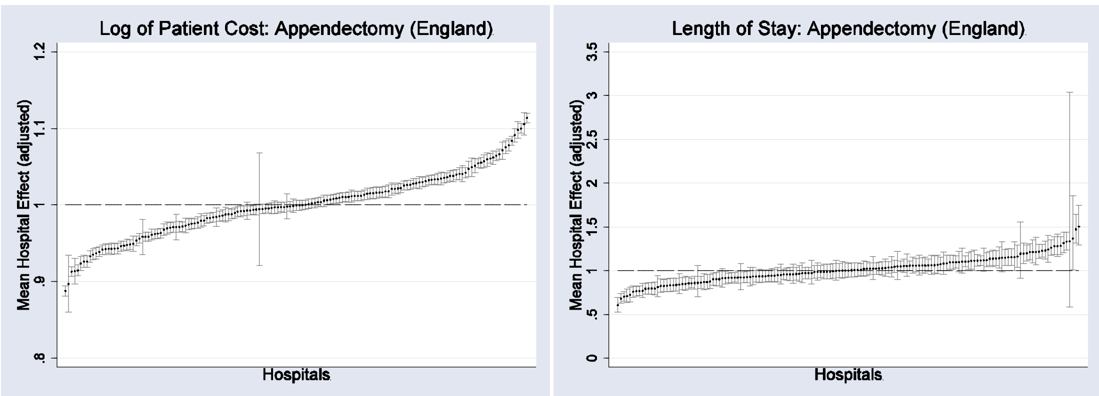

Figure 5: Hospital fixed effects: appendectomy

In the cost graph in Figure 5, one middle-ranking hospital – Gloucestershire Hospitals NHS Foundation Trust – has a wide confidence interval around its mean value. This reflects a bimodal cost distribution in the raw patient-level cost data for this hospital, which was not explained by the casemix variables in our model. In the LoS graph, the same hospital appears on the right-hand side, indicating substantial uncertainty around the mean value. This arises because a small proportion of patients had long stays, which the patient-level characteristics did not explain.

Overall, the relationship between each hospital's average costs and LoS was weak; the correlation was very small and not statistically significant (r=0.09; P=0.2698). As a consequence, each hospital's relative rank is sensitive to the choice of resource use measure, with only the Royal West Sussex NHS Trust among the top 5% on both measures. In both cost and LoS rankings, Birmingham Children's Hospital NHS Foundation Trust appears in the bottom 5%.

Box 5: Hospitals in top/bottom 5% by rank: Appendectomy

cost rank	LoS rank	Hospital Name
1	129	Sherwood Forest Hospitals NHS Foundation Trust
2	149	The Royal Wolverhampton Hospitals NHS Trust
3	52	North Tees & Hartlepool NHS Trust
4	136	Bedford Hospital NHS Trust
5	108	Sandwell & West Birmingham Hospitals NHS Trust
6	4	Royal West Sussex NHS Trust
7	40	Kingston Hospital NHS Trust
8	135	University Hospitals of Morecambe Bay NHS Trust
144	151	Birmingham Children's Hospital NHS Foundation Trust
145	25	Doncaster & Bassetlaw Hospitals NHS Foundation Trust
146	32	York Hospitals NHS Foundation Trust
147	132	Great Ormond Street Hospital For Children NHS Trust
148	74	Blackpool, Fylde & Wyre Hospitals NHS Trust
149	116	Southport and Ormskirk Hospital NHS Trust
150	126	Scarborough and North East Yorkshire Health Care NHS Trust
151	118	Leeds Teaching Hospitals NHS Trust

LoS rank	cost rank	Hospital Name
1	132	West Suffolk Hospitals NHS Trust
2	30	Heatherwood & Wexham Park Hospitals NHS Trust
3	123	Frimley Park Hospital NHS Foundation Trust
4	6	Royal West Sussex NHS Trust
5	85	Winchester & Eastleigh Healthcare NHS Trust
6	25	Yeovil District Hospital NHS Foundation Trust
7	120	Plymouth Hospitals NHS Trust
8	24	Maidstone & Tunbridge Wells NHS Trust
144	117	Sheffield Teaching Hospitals NHS Foundation Trust
145	39	Northern Lincolnshire & Goole Hospitals NHS Trust
146	40	South Warwickshire General Hospitals NHS Trust
147	84	Aintree University Hospitals NHS Foundation Trust
148	64	Gloucestershire Hospitals NHS Foundation Trust
149	2	The Royal Wolverhampton Hospitals NHS Trust
150	127	United Bristol Healthcare NHS Trust
151	144	Birmingham Children's Hospital NHS Foundation Trust

Breast cancer

Literature Review

- Downing et al., (2009) identified the predictors of LoS for breast cancer patients in two regions of England over the period 1997/98 to 2004/05.
  - A multi-level model with patients clustered within surgical teams and NHS Trusts was used to examine associations between LoS and a range of factors.
  - Older age, advanced stage breast cancer at time of diagnosis, presence of comorbidities, lymph node excision and reconstructive surgery were associated with increased LoS.
  - The study identified significant unexplained variation in LoS amongst Trusts and surgical teams.
- Participants of the EuroDRG project used the same methodology as this CHE Research Paper to predict the impact of DRGs and a series of patient characteristics on cost and LoS for breast cancer in 10 countries (Scheller-Kreinsen et al., 2012).
  - Compared to those aged 51-69, those over 70 had significantly higher costs and LoS while those aged less than 50 had shorter stays.
  - Having a higher number of procedures significantly increased cost and LoS in all countries, while a higher number of diagnoses followed a similar pattern in seven countries.
  - Postoperative wound infection increased costs and LoS in most countries.
  - Patients with a main diagnosis of "carcinoma in situ of breast" tended to have significantly lower costs and LoS while having a plastic operation had the opposite effect – increasing both cost and LoS.
  - Patients who received a total mastectomy had significantly higher costs and LoS.

Patient-level analysis

We analysed the costs and LoS of 30,025 women with breast cancer who were treated in 139 hospitals. Detailed results are provided in Table 6. In Box 6 below, we summarise variables that are significant (P<0.001) explanators of variations in patient cost or LoS.

Box 6: Variables that are significant explanators of cost or LOS for breast cancer

Variables	Our Findings
Dependent variables (mean)	Cost – £2,083 LoS – 7.5
Demographics	Patients aged over 71 had higher costs than those aged between 50 and 57 while LoS increased with age among patients over 64. LoS was also longer among patients living in poorer areas.
Admission/ Discharge	Although they constituted less than 0.5% of the total sample, emergency cases and those ending in a transfer to another hospital had over 50% longer LoS. Patients treated by more than one consultant typically had longer LoS.
Case Complexity	A higher number of diagnoses or procedures was associated with increased cost and LoS. However, LoS was 8% shorter when hypertension was diagnosed.
HRGs	The impact on cost and LoS of patient HRG was frequently significantly different from the reference HRG "Major breast procedure category 3" (JA06Z), with coefficients rising broadly in line with the tariff. Figure 6 shows how cost (in natural units) varied by HRG.
Treatment Specific	Patients diagnosed with a carcinoma in situ of breast had 3% lower cost and 8% shorter LoS. Cost and LoS were higher if patients underwent lymph node resection, plastic operation on breast or total mastectomy. The impacts of "Malignant neoplasm of breast" and "Secondary and unspecified malignant neoplasm of lymph node" on cost and LoS were sensitive to whether or not quality was accounted for.
Quality	In the 0.2% of cases where post operative infection occurred, patient cost was 17% higher and LoS 93% longer. Patient LoS also increased if diagnosed with a UTI, by 60% and 34% respectively.

Table 6: Cost and LoS in breast cancer patients: patient-level analysis

Explanatory variable	mean	sd	Log of cost				LoS #			
			Full Model		*Partial Model*		*Full Model*		*Partial Model*	
			β	se	β	se	β	se	β	se
Age 1: 1 to 49	0.198	0.399	0.000	0.005	0.008	0.005	0.994	0.012	1.038**	0.014
Age 2: 50 to 57	0.203	0.403	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Age 3: 58 to 64	0.220	0.414	0.002	0.004	0.003	0.005	1.033**	0.012	1.040**	0.014
Age 4: 65 to 71	0.187	0.390	0.007	0.005	0.008	0.005	1.087***	0.013	1.101***	0.016
Age 5: 72+	0.191	0.393	0.023***	0.005	0.041***	0.005	1.275***	0.016	1.448***	0.020
Gender	0.000	0.000	*omitted*		*omitted*		*omitted*		*omitted*	
Socioeconomic status	0.142	0.111	0.018	0.014	0.015	0.014	1.188***	0.044	1.167***	0.048
Emergency admission DV	0.003	0.055	0.138*	0.064	0.138*	0.064	1.777***	0.196	1.930***	0.214
Transfer-in DV	0.002	0.044	0.060	0.046	0.060	0.046	1.113	0.137	1.106	0.126
Transfer-out DV	0.004	0.061	0.052	0.027	0.069**	0.027	1.562***	0.173	1.774***	0.190
Total number diagnoses	2.258	1.538	0.007***	0.002	0.011***	0.002	1.064***	0.005	1.098***	0.005
Total number procedures	3.360	1.103	0.020***	0.002	0.025***	0.002	1.091***	0.005	1.093***	0.005
One non-severe Charlson comorbidity	0.114	0.318	0.000	0.005	-0.003	0.005	1.002	0.014	0.981	0.015
At least 1 severe or 2 non-severe Charlson comorbidities	0.017	0.129	-0.010	0.012	-0.014	0.012	1.013	0.035	1.010	0.035
Hypertension comorbidity DV	0.197	0.398	-0.002	0.004	-0.007	0.004	0.923***	0.012	0.890***	0.013
Obesity comorbidity DV	0.007	0.083	-0.006	0.014	-0.009	0.015	0.994	0.047	0.984	0.052
HRG1: JA09B DV; Intermediate Breast Proc w/o cc	0.126	0.332	-0.580***	0.008	-0.670***	0.006	0.697***	0.014	0.455***	0.008
HRG2: JA09A DV; Intermediate Breast Proc w cc	0.078	0.268	-0.478***	0.008	-0.570***	0.006	0.814***	0.017	0.529***	0.011
HRG3: JA07B DV; Major Breast Proc cat2 w icc	0.166	0.372	-0.227***	0.006	-0.295***	0.004	0.847***	0.013	0.624***	0.009
HRG4: JA06Z DV; Major Breast Proc cat3	0.303	0.459	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
HRG5: JA07C DV; Major Breast Proc cat2 w/o cc	0.271	0.445	-0.333***	0.006	-0.401***	0.004	0.752***	0.012	0.556***	0.008
HRG6: JA07A DV; Major Breast Proc cat2 w mcc	0.013	0.113	-0.106***	0.016	-0.163***	0.016	0.990	0.047	0.782***	0.040
HRG7: JA05Z DV; Pedicled Myocutaneous Breast Recon w/o Prosthesis	0.023	0.150	0.290***	0.018	0.410***	0.015	1.073**	0.029	1.606***	0.032
HRG8: Other non-reference HRG DV	0.021	0.142	-0.345***	0.022	-0.389***	0.024	0.903**	0.031	0.803***	0.030
Carcinoma in situ of breast	0.122	0.327	-0.032***	0.006	-0.033***	0.006	0.919***	0.013	0.932***	0.016
Malignant neoplasm of breast	0.007	0.081	-0.010	0.016	0.020	0.016	0.970	0.044	1.174***	0.054
Secondary and unspecified malignant neoplasm of lymph nodes	0.162	0.369	0.002	0.004	0.015***	0.004	0.965**	0.011	1.025*	0.012
Metastasis	0.005	0.073	-0.030	0.023	-0.018	0.023	1.075	0.076	1.107	0.075
Lymph node resection	0.439	0.496	0.047***	0.005			1.143***	0.015		
Plastic operation on breast	0.051	0.220	0.115***	0.011			1.299***	0.028		
Total Mastectomy	0.395	0.489	0.116***	0.003			2.063***	0.020		
Multiple episode DV	0.008	0.090	0.017	0.033			1.602***	0.095		
Mortality DV	0.000	0.015	0.084	0.051			1.382	0.286		
Adverse event DV	0.001	0.029	0.002	0.060			1.279	0.203		
Infection DV: UTI	0.002	0.045	0.099**	0.037			1.339***	0.108		
Infection DV: post-operative infection	0.002	0.047	0.158***	0.036			1.932***	0.179		
Infection DV: C difficile	0.000	0.012	0.022	0.080			1.917	0.986		
Constant			7.616***	0.009	7.704***	0.008	1.144***	0.027	1.941***	0.046
alpha							0.044***	0.005	0.117***	0.005
N			30025		30025		30025		30025	
r2_a / adjusted deviance r^2			0.736		0.722		0.535		0.391	

Exponentiated coefficients; DV: dummy variable; w: with; w/o: without; cc: complications and comorbidities; icc: intermediate cc; mcc: major cc; UTI: urinary tract infection.

* p < 0.05, ** p < 0.01, *** p < 0.001

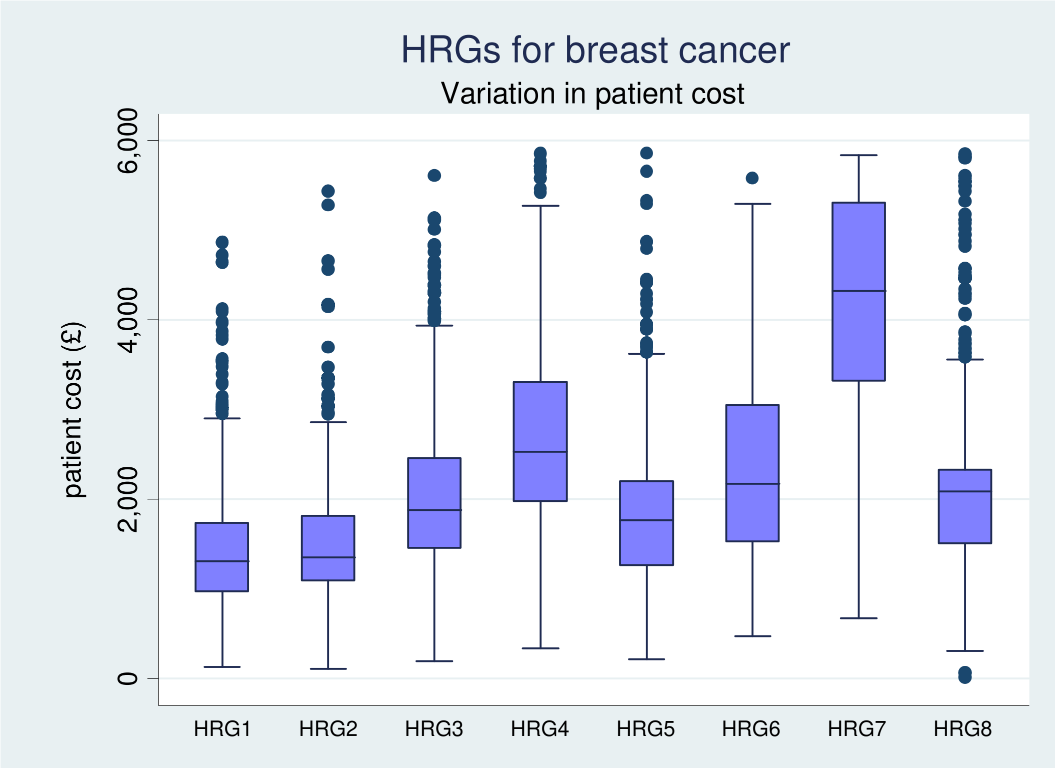

Figure 6: Variation in patient cost by HRG: breast cancer

Notes: see Table 6 for HRG definitions. HRG4: is the reference category (most populated HRG) for the breast cancer analysis. HRGs are ranked in ascending order of PbR tariff.
Box plot shows, from top to bottom: outside values (dots), upper adjacent value, 75th percentile (upper hinge), median, 25th percentile (lower hinge) and lower adjacent value.

Hospital performance

Our analysis included 139 hospitals that cared for patients suffering breast cancer. The variation in unexplained average hospital costs ranged from 11% below to 10% above the national mean; for LoS, the corresponding figures were 72% and 118%. None of the hospital characteristics that we examined was significant in explaining this variation.

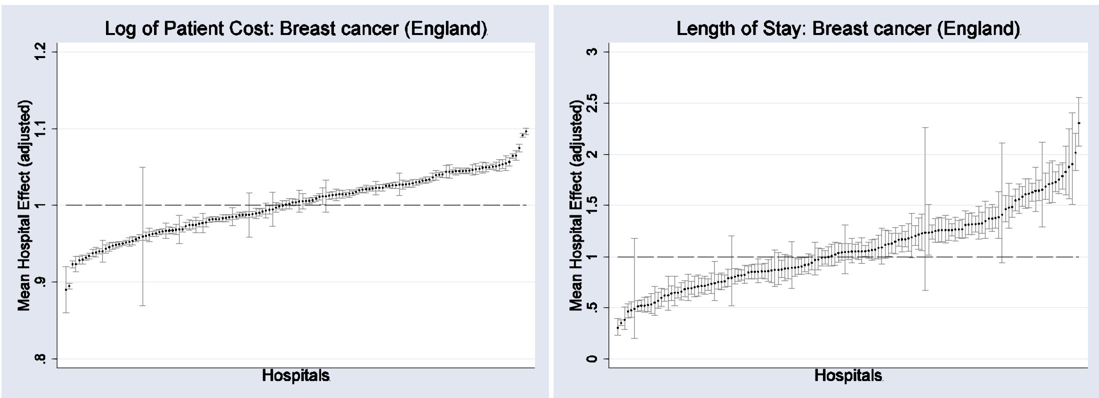

Figure 7: Hospital fixed effects: breast cancer

Average costs and LoS were more closely correlated for breast cancer (r=0.51; P<0.05) than for any of the other treatments we examined. Most of the hospitals where average costs were highest were also among those hospitals with the longest average LoS, notably Leeds Teaching Hospitals NHS Trust, Queen Elizabeth Hospital NHS Trust, Christie Hospital NHS Foundation Trust, Mid Yorkshire Hospitals NHS Trust, and

Airedale NHS Trust. In the both graphs in Figure 7, one hospital has a wide confidence interval. This hospital, the Princess Alexandra Hospital NHS Trust, undertook fewer than 10 mastectomies. For these patients, costs and LoS were highly variable and our models were unable to account for the spread of these data.

Box 7: Hospitals in top/bottom 5% by rank: breast cancer (mastectomy)

cost rank	LoS rank	Hospital Name
1	111	Blackpool, Fylde & Wyre Hospitals NHS Trust
2	50	South Warwickshire General Hospitals NHS Trust
3	84	Frimley Park Hospital NHS Foundation Trust
4	11	Scarborough & North East Yorkshire Health Care NHS Trust
5	15	Northampton General Hospital NHS Trust
6	12	The Rotherham NHS Foundation Trust
7	48	East Lancashire Hospitals NHS Trust
133	125	Basildon & Thurrock University Hospitals NHS Foundation Trust
134	106	Salford Royal NHS Foundation Trust
135	128	Mid Yorkshire Hospitals NHS Trust
136	135	Christie Hospital NHS Foundation Trust
137	130	Queen Elizabeth Hospital NHS Trust
138	131	Leeds Teaching Hospitals NHS Trust
139	95	Essex Rivers Healthcare NHS Trust

LoS rank	cost rank	Hospital Name
1	31	Hereford Hospitals NHS Trust
2	52	Southampton University Hospitals NHS Trust
3	69	North West London Hospitals NHS Trust
4	71	Guy's & St Thomas' NHS Foundation Trust
5	39	Luton & Dunstable Hospital NHS Foundation Trust
6	49	North Bristol NHS Trust
7	17	North Tees & Hartlepool NHS Trust
133	86	Barnet & Chase Farm Hospitals NHS Trust
134	95	Northern Lincolnshire & Goole Hospitals NHS Trust
135	136	Christie Hospital NHS Foundation Trust
136	35	Portsmouth Hospitals NHS Trust
137	79	Homerton University Hospital NHS Foundation Trust
138	126	Royal Free Hampstead NHS Trust
139	132	Airedale NHS Trust

Childbirth

Literature review

- Laudicella et al., (2010) examined cost variations across obstetrics departments in England.
    - They used a two-stage multi-level approach and patient level data for almost one million patients discharged from obstetrics departments in 2005/06.
    - Compared to the reference case (normal delivery w/o cc), costs of other maternity HRGs were higher.
    - They also found that a higher number of procedures and diagnoses significantly increased costs.
- Comas et al., (2011) used a multivariate regression model to estimate the costs of childbirth in Spain (Catalonia).
    - Using patient level data, they found that the costs and LoS for caesarean sections and assisted deliveries were significantly higher than for normal delivery.
- Participants in the EuroDRG project used a hierarchical model to analyse the drivers of cost and LoS for childbirth in ten European countries (Or et al., 2012).
    - They found that younger mothers (<21) had significantly longer lengths of stay and higher costs in most countries, whilst older mothers (>35) had longer stays in Austria and Ireland
    - Being transferred into hospital significantly increased cost and LoS in most countries while transfers out of hospital significantly reduced LoS and cost
    - Having multiple deliveries significantly increased LoS and costs in all counties, as did having a c-section
    - Cases of stillbirth led to shorter stays but did not entail major differences in cost.

Patient-level analysis

Data were available for 549,036 women undergoing childbirth in 144 hospitals, making this the largest sample of patients for the set of treatments we consider. Results of our analyses of their costs and LoS are reported in Table 7. Patient characteristics that are significant (P<0.001) explanators of variations in cost or LoS are summarised in Box 8 below.

Box 8: Patient characteristics that are significant explanators of variations in cost or LOS for childbirth

Variables	Our Findings
Dependent variables (mean)	Cost – £1,611 LoS – 2.4
Demographics	Women aged over 35 had 1% higher cost and 4% longer LoS than the 24-27 age group. Costs and LoS were both significantly higher among women from poorer areas.
Admission/ Discharge	Emergency cases had 3% higher cost and 18% longer LoS. Patients transferred in had 3% higher cost and 19% longer LoS while those transferred out were 5% cheaper and had 25% shorter stays. Women cared for by multiple consultants had higher cost and LoS.
Case Complexity	Patients with a greater total number of diagnoses or procedures had higher costs and LoS. However, women diagnosed with obesity had 10% shorter stays. LoS was 12% higher in patients who were diagnosed with at least two non-severe, or with one major, Charlson comorbidity. However, if a single non-severe Charlson comorbidity was diagnosed, patient costs were 1% lower and LoS 8% shorter.
HRGs	Relative to the base HRG "normal delivery without complications in adults" (NZ01B), patient cost was higher for all other specified HRGs by between 3% and 101%. Cost rose in line with the tariff paid for each HRG. Patient LoS followed the same general pattern as cost, ranging from 11% to 134% higher than the reference group.
Treatment Specific	Patient cost and LoS were higher when multiple births or an episiotomy occurred. In the 0.5% of still birth cases, LoS was 9% shorter.
Quality	Spells involving adverse events had higher cost and LoS. Patients diagnosed with a UTI or C. difficile had longer LoS of 14% and 64% respectively (Figure 8). However, the C difficile affected less than 0.1% of women.

Table 7: Cost and LoS in childbirth patients: patient-level analysis

Explanatory variable	mean	sd	Log of cost				LoS #			
			Full Model		*Partial Model*		*Full Model*		*Partial Model*	
			β	se	β	se	β	se	β	se
Age 1: 1 to 23	0.214	0.410	0.004**	0.002	0.004**	0.002	0.998	0.003	0.999	0.003
Age 2: 24 to 27	0.200	0.400	ref	ref	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Age 3: 28 to 31	0.226	0.418	0.000	0.002	0.000	0.002	1.007*	0.003	1.008*	0.003
Age 4: 32 to 35	0.207	0.405	0.002	0.002	0.001	0.002	1.009**	0.003	1.007*	0.003
Age 5: 36+	0.153	0.360	0.011***	0.002	0.009***	0.002	1.035***	0.004	1.030***	0.004
Gender	0.000	0.000	omitted		*omitted*		*omitted*		*omitted*	
Socioeconomic status	0.193	0.140	0.033***	0.004	0.028***	0.004	1.112***	0.010	1.097***	0.01
Emergency admission DV	0.004	0.067	0.028***	0.008	0.030***	0.008	1.179***	0.021	1.184***	0.021
Transfer-in DV	0.007	0.083	0.031***	0.006	0.030***	0.006	1.183***	0.015	1.181***	0.015
Transfer-out DV	0.006	0.076	-0.049***	0.007	-0.048***	0.007	0.753***	0.013	0.755***	0.014
Total number diagnoses	3.215	1.432	0.025***	0.000	0.026***	0.000	1.103***	0.001	1.107***	0.001
Total number procedures	2.408	1.215	0.039***	0.000	0.043***	0.000	1.095***	0.001	1.108***	0.001
One non-severe Charlson comorbidity	0.032	0.177	-0.014***	0.003	-0.017***	0.003	0.921***	0.005	0.916***	0.005
At least 1 severe or 2 non-severe Charlson comorbidities	0.001	0.029	0.041**	0.015	0.038*	0.015	1.128***	0.037	1.120***	0.038
Hypertension comorbidity DV	0.000	0.016	0.016	0.033	0.018	0.033	1.144	0.083	1.145	0.083
Obesity comorbidity	0.006	0.078	-0.002	0.007	-0.008	0.007	0.895***	0.010	0.885***	0.01
HRG1: NZ01B DV; Normal delivery >18 w/o cc	0.535	0.499	ref	ref	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
HRG2: NZ01D DV; Normal delivery <19 w/o cc	0.025	0.156	0.033***	0.004	0.033***	0.004	1.108***	0.008	1.109***	0.008
HRG3: NZ02B DV; Assisted delivery w/o cc	0.034	0.181	0.209***	0.002	0.230***	0.002	1.209***	0.006	1.276***	0.007
HRG4: NZ01A DV; Normal delivery >18 with cc	0.131	0.338	0.341***	0.002	0.341***	0.002	1.505***	0.006	1.505***	0.006
HRG5: NZ02A DV; Assisted delivery w cc	0.016	0.127	0.419***	0.004	0.436***	0.003	1.459***	0.012	1.531***	0.012
HRG6: NZ03A DV; Caesarean Section >18	0.086	0.280	0.519***	0.002	0.514***	0.001	2.070***	0.007	2.041***	0.007
HRG7: NZ03C DV; Caesarean Section w cc	0.150	0.357	0.700***	0.001	0.696***	0.001	2.350***	0.007	2.305***	0.006
HRG8: Other non-reference HRG DV	0.023	0.149	0.329***	0.004	0.336***	0.004	1.745***	0.012	1.741***	0.012
Stillbirth	0.005	0.072	-0.010	0.008	-0.017*	0.008	0.907***	0.016	0.889***	0.016
Multiple delivery	0.015	0.120	0.041***	0.003	0.035***	0.003	1.300***	0.009	1.287***	0.009
Episiotomy	0.143	0.350	0.036***	0.001			1.109***	0.004		
Multiple episode DV	0.043	0.203	0.089***	0.002			1.091***	0.006		
Mortality DV	0.000	0.004	-0.080	0.135			0.739	0.317		
Adverse event DV	0.020	0.141	0.044***	0.003			1.167***	0.007		
Infection DV: UTI	0.007	0.083	0.004	0.006			1.141***	0.014		
Infection DV: post-operative infection	0.000	0.005	0.112	0.116			1.320	0.198		
Infection DV: C difficile	0.000	0.006	0.137	0.096			1.728***	0.239		
Constant			6.856***	0.002	6.852***	0.002	0.899***	0.004	0.891***	0.004
alpha							0.064***	0.003	0.065***	0.003
N			549036		549036		549036		549036	
r2_a / adjusted deviance r^2			0.547		0.546		0.341		0.339	
Type							nbreg		nbreg	

Exponentiated coefficients; DV: dummy variable; w: with; w/o: without; cc: complications and comorbidities; icc: intermediate cc; mcc: major cc; UTI: urinary tract infection.

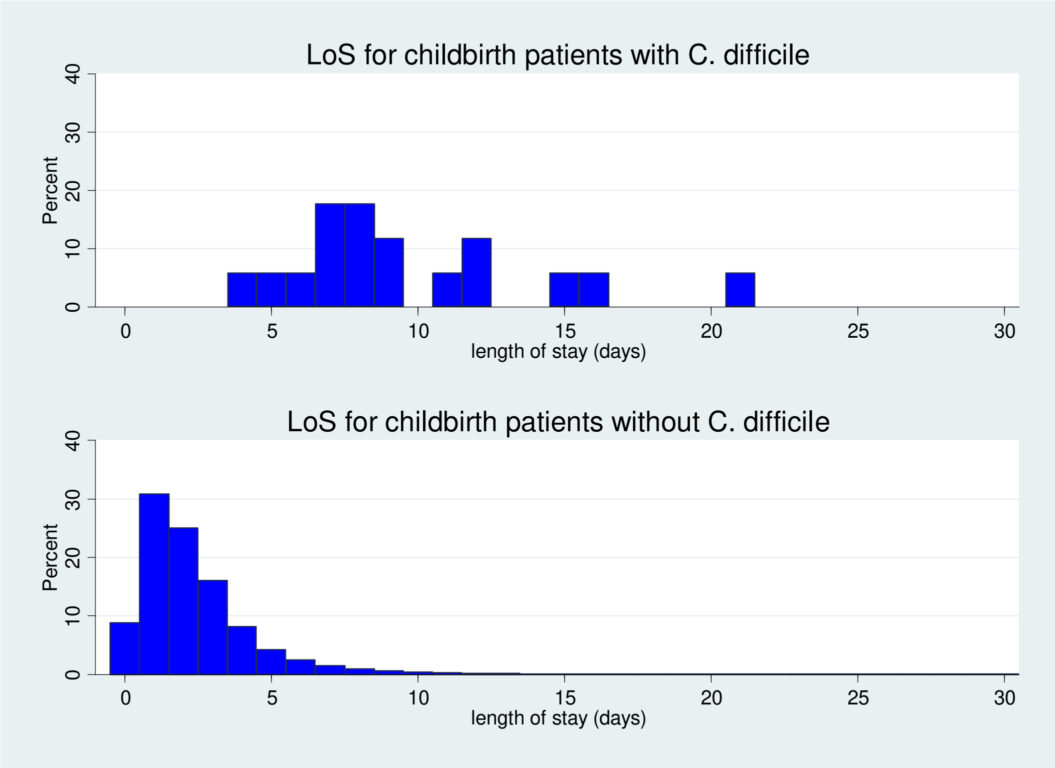

Figure 8: Variation in LoS by C. difficile: childbirth

Hospital performance

There was a wide variation in the fixed effects capturing average hospital costs, purged of the influence of patient characteristics. These average costs ranged from 18% below the national hospital mean to 9% above. Variation in average LoS was more pronounced (range: 32% below to 62% above the national mean). None of the hospital level variables we tested explained between-hospital variation in cost or LoS.

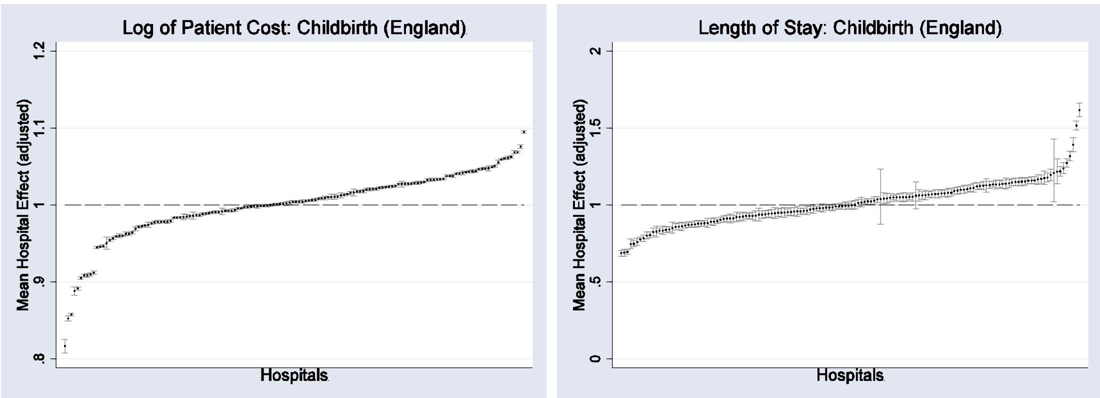

Figure 9: Hospital fixed effects: childbirth

There was little relation between cost and LoS for those hospitals at the lower end of either distribution. A couple of hospitals with relatively high average costs also had long average LoS, these being Shrewsbury & Telford Hospital NHS Trust, and Northumbria Healthcare NHS Foundation Trust. There was no correlation between average costs and LoS (r=-0.02; P=0.7901).

Box 9: Hospitals in top/bottom 5% by rank: childbirth

cost rank	LoS rank	Hospital Name
1	133	York Hospitals NHS Foundation Trust
2	129	The Royal Wolverhampton Hospitals NHS Trust
3	107	Poole Hospital NHS Trust
4	138	Weston Area Health NHS Trust
5	101	Queen Elizabeth Hospital NHS Trust
6	52	North Cheshire Hospitals NHS Trust
7	13	Worthing & Southlands Hospitals NHS Trust
138	65	Barking, Havering & Redbridge Hospitals NHS Trust
139	12	Harrogate & District NHS Foundation Trust
140	127	Northumbria Healthcare NHS Foundation Trust
141	134	Shrewsbury & Telford Hospital NHS Trust
142	85	Tameside & Glossop Acute Services NHS Trust
143	51	Gateshead Health NHS Foundation Trust
144	113	University Hospitals Of Morecambe Bay NHS Trust

LoS rank	cost rank	Hospital Name
1	94	Royal West Sussex NHS Trust
2	18	West Suffolk Hospitals NHS Trust
3	118	Doncaster & Bassetlaw Hospitals NHS Foundation Trust
4	9	University Hospital Of North Staffordshire NHS Trust
5	30	Bedford Hospital NHS Trust
6	86	Barnet & Chase Farm Hospitals NHS Trust
7	46	University Hospitals Of Leicester NHS Trust
138	4	Weston Area Health NHS Trust
139	36	Barts & The London NHS Trust
140	134	Plymouth Hospitals NHS Trust
141	68	South Warwickshire General Hospitals NHS Trust
142	49	Stockport NHS Foundation Trust
143	121	Central Manchester & Manchester Children's University Hospitals NHS Trust
144	56	King's College Hospital NHS Foundation Trust

Cholecystectomy

Literature review

- Carbonell et al., (2005) used data from the U.S. Healthcare Cost and Utilisation Project Nationwide Inpatient Sample database for the year 2000 to examine the influence of patient and hospital characteristics on cholecystectomy costs (with charges as a proxy) and LoS.
  - They found that both LoS and costs were significantly lower for laparoscopic cholecystectomy.
  - Increasing age was associated with longer LoS and higher costs.
- A study by Kuy et al., (2011) used U.S. inpatient data over a 7 year period (1999-2006) and found that older patients had longer LoS and higher costs than younger patients.
- As part of the EuroDRG project, researchers used a hierarchical model to identify the drivers of cost and LoS for cholecystectomy at individual and hospital level across ten European countries (Paat-Ahi et al., 2012).
  - They found that increasing age had a significantly positive effect on cost and LoS in all countries.
  - Patients with more diagnoses and procedures had higher costs and LoS in most countries.
  - Emergency cases typically had significantly higher costs and longer LoS, while patients who died in hospital had significantly shorter stays in all countries.
  - Laparoscopic procedures significantly reduced cost and LoS compared to open procedures.

Patient-level analysis

Results from our analyses of the costs and LoS for the 43,917 patients who had cholecystectomy in 148 hospitals during 2007/8 are reported in Table 8. Significant (P<0.001) variables are highlighted below.

Box 10: Patient characteristics that are significant explanators of variations in cost or LOS for cholecystectomy

Variables	Our Findings
Dependent variables (mean)	Cost – £1,971 LoS – 2.3
Demographics	Patients aged over 57 had 3% higher costs than those aged 37-47. Patient LoS also increased with age. Patients living in poorer areas had higher costs and stayed longer than those from better off areas. Male patients had longer LoS but this effect was no longer significant at the 0.1% level when quality measures were included in the model.
Admission/ Discharge	The 10% of cases treated as emergencies cost 66% more and stayed 2.3 times longer than elective cases. These differences translate to an increase of approximately £1,000 and 5 days respectively per case. Patients transferred out stayed 36% longer than patients treated in a single hospital. Patients cared for by more than one consultant stayed in hospital 33% longer than those under the care of a single consultant.
Case Complexity	Patients diagnosed with a larger number of conditions had higher cost and LoS. A higher number of procedures performed also increased patient cost and LoS. The more specific comorbidities considered did not significantly impact on either dependant variable. 17% of patients were diagnosed with hypertension. These appear to have 9% lower LoS, but this impact is only significant at the 0.1% level when quality was not taken into account. .
HRGs	Relative to the base HRG “Cholecystectomy without complications” (GA10B), patients had higher costs and longer LoS if complications occurred (GA10A, and GA07A) or were assigned to a more complex category 3 HRG (GA07B and GA07A). The broader HRG covering general abdominal procedures with major complications (FZ12A) had a similar impact on patient cost to GA07B but no significant impact on LoS.
Treatment Specific	When successful, a laparoscopic cholecystectomy reduced patient cost by 7% and LoS by 49%. However, if the laparoscopic approach failed, patients had 5% higher costs and 17% longer LoS than patients that had the open procedure.
Quality	For the 0.3% of patients that suffered a post operative infection LoS was 85% longer.

Table 8: Cost and LoS in cholecystectomy patients: patient-level analysis

Explanatory variable	mean	sd	**Log of cost** *Full Model*		*Partial Model*		**LoS #** *Full Model*		*Partial Model*	
			β	se	β	se	β	se	β	se
Age 1: 1 to 36	0.209	0.407	-0.006	0.004	-0.007	0.004	0.950***	0.013	0.932***	0.013
Age 2: 37 to 47	0.212	0.409	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Age 3: 48 to 57	0.193	0.395	0.013**	0.004	0.014**	0.004	1.064***	0.015	1.075***	0.016
Age 4: 58 to 67	0.205	0.404	0.029***	0.004	0.031***	0.004	1.151***	0.021	1.183***	0.022
Age 5: 68+	0.181	0.385	0.063***	0.005	0.067***	0.005	1.400***	0.021	1.462***	0.023
Gender	0.235	0.424	0.004	0.003	0.008*	0.003	1.033**	0.011	1.094***	0.013
Socioeconomic status	0.164	0.122	0.045***	0.012	0.046***	0.012	1.241***	0.048	1.245***	0.053
Emergency admission DV	0.097	0.296	0.506***	0.007	0.513***	0.007	3.333***	0.048	3.789***	0.049
Transfer-in DV	0.006	0.075	-0.05	0.027	-0.048	0.027	1.163*	0.083	1.193*	0.098
Transfer-out DV	0.003	0.058	0.061	0.032	0.076*	0.032	1.355***	0.121	1.554***	0.143
Total number diagnoses	2.268	1.665	0.006***	0.002	0.010***	0.001	1.077***	0.005	1.117***	0.005
Total number procedures	2.318	0.889	0.035***	0.003	0.033***	0.002	1.203***	0.008	1.188***	0.007
One non-severe Charlson comorbidity	0.135	0.342	0.014**	0.005	0.011*	0.005	0.99	0.014	0.965*	0.015
At least 1 severe or 2 non-severe Charlson comorbidities	0.024	0.154	0.012	0.011	0.007	0.011	1.02	0.031	0.978	0.033
Hypertension comorbidity DV	0.166	0.372	0.006	0.004	0.002	0.004	0.945**	0.02	0.908***	0.019
Obesity comorbidity DV	0.022	0.147	0.01	0.009	0.011	0.009	1.041	0.029	1.042	0.03
HRG1: GA10B DV; Cholecystectomy w/o cc	0.757	0.429	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
HRG2: GA10A DV; Cholecystectomy wcc	0.162	0.369	0.188***	0.005	0.191***	0.005	1.269***	0.018	1.303***	0.02
HRG3: GA08B DV; Hepatobiliary Proc cat2 w/o cc	0.012	0.111	-0.011	0.03	0.002	0.031	0.983	0.056	1.114	0.067
HRG4: GA07B DV; Hepatobiliary Proc cat3 w/o cc	0.013	0.115	0.333***	0.018	0.357***	0.018	1.686***	0.064	2.194***	0.087
HRG5: FZ12A DV; General Abdominal: v. major/major proc w mcc	0.018	0.133	0.301***	0.018	0.310***	0.018	1.089*	0.044	1.194***	0.05
HRG6: GA07A DV; Hepatobiliary Proc cat3 wcc	0.01	0.099	0.536***	0.022	0.576***	0.022	1.580***	0.067	2.225***	0.094
HRG7: Other non-reference HRG DV	0.027	0.162	0.270***	0.018	0.299***	0.018	1.538***	0.048	2.051***	0.065
Laparoscopy DV	0.898	0.303	-0.071***	0.008			0.512***	0.011		
Failed laparoscopy DV	0.044	0.205	0.052***	0.011			1.174***	0.029		
Multiple episode DV	0.049	0.215	0.003	0.009			1.331***	0.028		
Mortality DV	1E-03	0.031	-0.073	0.08			0.625**	0.109		
Adverse event DV	0.009	0.093	0.032	0.022			1.071	0.062		
Infection DV: UTI	0.002	0.046	0.061	0.038			1.317**	0.129		
Infection DV: post-operative infection	0.003	0.055	0.044	0.034			1.848***	0.134		
Infection DV: C difficile	5E-04	0.021	-0.007	0.093			1.482	0.303		
Constant			7.313***	0.009	7.245***	0.006	1.149***	0.03	0.596***	0.012
alpha							0.194***	0.014	0.248***	0.015
N			43917		43917		43917		43917	
r2_a / adjusted deviance r^2			0.629		0.626		0.598		0.544	

Exponentiated coefficients; DV: dummy variable; w: with; w/o: without; cc: complications and comorbidities; icc: intermediate cc; mcc: major cc; UTI: urinary tract infection.
* p < 0.05, ** p < 0.01, *** p < 0.001

Hospital performance

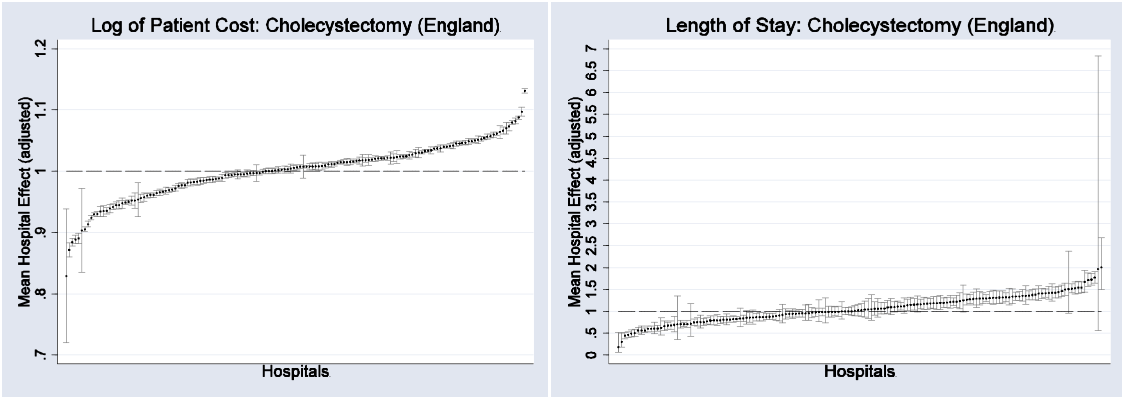

Figure 10: Hospital fixed effects: cholecystectomy

Patients treated at Gloucestershire Hospitals NHS Foundation Trust had both the lowest costs and shortest LoS nationally, after adjusting for casemix differences. Hospital costs ranged from 17% below to 13% above the national mean hospital cost; the corresponding figures for LoS were 82% and 90% respectively. Overall there was a positive rank correlation between average cost and LoS (r=0.39; P<0.05), and most of the hospitals at the extreme upper end of the cost distribution were also at the upper end of the LoS distribution. In Weston Area Health NHS Trust, one patient had a stay of 285 days. This underlies the wide confidence interval (i.e. high level of uncertainty) around the estimate of the mean LoS for this hospital (Figure 10).

Box 11: Hospitals in top/bottom 5% by rank: cholecystectomy

cost rank	LoS rank	Hospital Name
1	1	Gloucestershire Hospitals NHS Foundation Trust
2	76	Kingston Hospital NHS Trust
3	94	South Warwickshire General Hospitals NHS Trust
4	45	Southampton University Hospitals NHS Trust
5	67	Salford Royal NHS Foundation Trust
6	19	United Bristol Healthcare NHS Trust
7	65	York Hospitals NHS Foundation Trust
142	98	Scarborough & North East Yorkshire Health Care NHS Trust
143	127	Lancashire Teaching Hospitals NHS Foundation Trust
144	132	Barking, Havering & Redbridge Hospitals NHS Trust
145	144	Dudley Group Of Hospitals NHS Trust
146	130	Leeds Teaching Hospitals NHS Trust
147	133	University Hospitals Coventry & Warwickshire NHS
148	138	Birmingham Children's Hospital NHS Foundation Trust

LoS rank	cost rank	Hospital Name
1	1	Gloucestershire Hospitals NHS Foundation Trust
2	23	The Royal Wolverhampton Hospitals NHS Trust
3	73	Winchester & Eastleigh Healthcare NHS Trust
4	9	Royal Berkshire Hospital NHS Foundation Trust
5	31	Hinchingbrooke Health Care NHS Trust
6	34	Buckinghamshire Hospitals NHS Trust
7	68	South Devon Healthcare NHS Foundation Trust
142	122	Wrightington, Wigan & Leigh NHS Trust
143	124	North Middlesex University Hospital NHS Trust
144	145	Dudley Group Of Hospitals NHS Trust
145	116	Sheffield Teaching Hospitals NHS Foundation Trust
146	120	Gateshead Health NHS Foundation Trust
147	63	Weston Area Health NHS Trust
148	133	Chelsea & Westminster Hospital NHS Foundation Trust

Coronary Artery Bypass Graft (CABG)

Literature review

- Bestawros et al., (2005) analysed cost data obtained for over 12,000 patients from 9 hospitals (4 in Canada and 5 in the U.S.). Log linear regression modelling was used to examine the impact of hospital LoS and costs for CABG.
  - Patients older than 75 years of age experienced 20% longer lengths of stay.
  - Comorbidities such as neoplasm, COPD and diabetes were all associated with increased stay ranging from 5% for diabetes patients to 17% for neoplasm.
  - Having had a previous myocardial infarction, hypertension or a lipid metabolism disorder reduced length of stay by 3% 6% and 7% respectively.
  - Being hospitalised in the US had the most significant impact on overall costs – US patients were 84% more costly than their Canadian equivalent.
  - Patients aged 75 and over had 11% higher cost.
  - Having preoperative congestive heart failure (CHF) increased costs by 45%
  - After adjusting for age and comorbidities, women had a 10% longer stay and a 7% increase in overall cost compared to men.
- Butterworth et al., (2000) analysed data from surveys in 1995 and 1997 to investigate the effect of gender on different aspects of LoS.
  - Mixed-effects linear models were used to test for associations between gender and LoS.
  - Covariates included age, weight, DRG, congestive heart failure, history of myocardial infarction, diabetes, and chronic obstructive lung disease.
  - After adjusting for preoperative covariates, women were found to have longer ICU (Intensive care unit) LoS and total postoperative LoS than males.
- Rosen et al., (1999) analysed detailed clinical data on Medicare patients to identify predictors of post operative LoS.
  - Significant predictors included increasing age, being female, history of chronic obstructive pulmonary disease, cerebrovascular disease and preoperative placement of an intra-aortic balloon pump.
  - They found significant hospital level variations even when adjusting for preoperative patient characteristics and postoperative complications.
- Saleh et al., (2009) analysed cost data on New York State residents who underwent a CABG in 2003.
  - Older patients and women had higher costs.
  - Higher costs were also associated with a lower ejection fraction, the duration of CAGB admission, the occurrence of myocardial infarction, carotid/cerebrovascular disease, congestive heart failure and renal failure.
- Naglie et al., (1999) found that CABG was more costly in older patients after adjusting for disease severity and co morbidities such as the presence of complications, diabetes hypertension and renal failure.
- Toor et al., (2009) examined whether complication rates and resource utilization among elderly patients undergoing CABG differed from their younger counterparts.
  - They collected demographic and clinical data from patients undergoing first-time isolated CABG.
  - Multivariate logistic regression analysis showed that age greater than or equal to 75 years was a significant predictor of postoperative LoS.
- Woods et al., (2003) assessed differences between men and women undergoing CABG surgery using an 8 year cohort study.
  - Using multiple regression analysis the authors looked at the impact of gender on 15 comorbidities and 13 health outcomes.

  - Women had more comorbidities at surgical presentation compared with men. In particular, women had significantly higher levels of diabetes, hypercholesterolemia, hypertension, previous cerebrovascular disease and reduced functional capacity.
  - Women had significantly higher rates of morality, intraoperative, renal and pulmonary complications as well as longer lengths of stay in hospital and in the intensive care unit.
  - After controlling for age and comorbidities, women still had significantly longer LoS.
- Kurki et al., (2003) used data from the New York State Statewide Planning and Research Cooperative System (SPARCS) database to investigate the association between preoperative risk factors and postoperative LoS in CABG patients.
  - Patients were subdivided into an emergency group and an elective group.
  - Using log regression analysis they found that the emergency group had a significantly longer LoS than elective patients.
- As part of the EuroDRG project researchers used a two-stage model using individual data to look at the predictors of cost and LoS for the treatment of CABG across hospitals and across ten countries (Gaughan et al., 2012).
  - Patients with a higher number of diagnoses and procedures had significantly higher costs and longer LoS in almost all countries,
  - Acute myocardial infarction (AMI) was the most frequently significant patient level indicator of cost and LoS. AMI was associated with lower LoS in Austria and lower costs in England but higher costs in Sweden,
  - Postoperative wound infection significantly increased LoS and costs.

Patient-level analysis

During 2007/8 18,875 patients received a CABG in 28 hospitals. Treatment is relatively expensive: on average, the cost of treating these patients amounted to £7,658 and LoS was 12.5 days. Results of our analyses of the patient characteristics that might influence cost or LoS are reported in Table 9. In Box 12 below, we highlight significant explanatory variables (P<0.001).

Box12: Patient characteristics that are significant explanators of variations in cost or LOS for CABG

Variables	Our Findings
Dependent variables (mean)	Cost – £7,658 LoS – 12.5
Demographics	An increase in patient age was associated with significantly longer LoS. Patients living in poorer areas and female patients also had longer LoS.
Admission/ Discharge	Patients transferred between hospitals had higher cost and longer LoS. Emergency cases were also associated with significantly longer LoS. When patients were cared for by more than one consultant, costs were 3% lower but LoS increased by 43%.
Case Complexity	Patients with more diagnoses or procedures had higher costs and longer LoS. Patients diagnosed with more than one Charlson comorbidity stayed 10% longer than those with none. Patients diagnosed with hypertension had 7% shorter LoS but the size of the impact was sensitive to the inclusion of quality variables.
HRGs	Relative to the base HRG "1st time CABG" (EA14Z), patients who underwent additional revascularisation procedures or catheterisation (EA20Z) had around 5% higher cost but 10% shorter stays. Cost was also significantly higher (by 8%) among patients categorised into the HRG "Intermediate Congenital Surgery" (EA25Z).
Treatment Specific	Patient LoS was higher where atrial fibrillation or renal failure was diagnosed. LoS was also longer when multiple vessels were bypassed or an additional valve procedure performed, but shorter in patients who had multiple CABGs or if a PTCA was performed. Of these variables, the absolute impact on LoS ranged from 5% (multiple vessel bypass) to 17% (renal failure). The occurrence of an AMI was associated with a 4% reduction in cost. However, this variable was only significant at the 0.1% level when quality measures were not included in the analysis.
Quality	Patients who died in hospital stayed 27% shorter than those discharged alive. Adverse events increased LoS, with the effect ranging from 17% (UTI) to 62% (post operative infection). Patients had higher costs if they suffered an adverse event or wound infection (Figure 11).

Table 9: Cost and LoS in CABG patients: patient-level analysis

			Log of cost				LoS #			
Explanatory variable	mean	sd	*Full Model*		*Partial Model*		*Full Model*		*Partial Model*	
			β	se	β	se	β	se	β	se
Age1: 1-59	0.217	0.412	-0.001	0.006	-0.002	0.006	0.949***	0.010	0.948***	0.011
Age2: 60-66	0.186	0.389	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Age3: 67-71	0.229	0.420	0.001	0.006	0.002	0.006	1.053***	0.012	1.060***	0.012
Age 4: 72-76	0.195	0.396	-0.002	0.006	0.000	0.006	1.107***	0.013	1.118***	0.014
Age 5: 77+	0.173	0.378	0.002	0.006	0.003	0.006	1.188***	0.016	1.211***	0.016
Gender	0.787	0.410	0.008	0.005	0.008	0.005	0.953***	0.010	0.950***	0.010
Socioeconomic status	0.153	0.118	0.030	0.017	0.030	0.017	1.216***	0.042	1.238***	0.046
Emergency admission DV	0.107	0.309	-0.005	0.010	-0.017	0.010	1.318***	0.021	1.533***	0.024
Transfer-in DV	0.253	0.435	0.0381***	0.005	0.0324***	0.005	1.125***	0.011	1.207***	0.012
Transfer-out DV	0.072	0.259	0.0317***	0.009	0.0404***	0.009	1.226***	0.023	1.263***	0.025
Total number diagnoses	6.570	3.298	0.0068***	0.001	0.0087***	0.001	1.033***	0.002	1.050***	0.002
Total number procedures	3.694	2.309	0.0212***	0.002	0.0197***	0.002	1.080***	0.003	1.103***	0.003
One non-severe Charlson comorbidity	0.295	0.456	0.003	0.004	0.001	0.004	1.027**	0.009	1.007	0.009
At least 1 severe or 2 non-severe Charlson comorbidities	0.167	0.373	0.0142*	0.006	0.009	0.006	1.101***	0.014	1.067***	0.015
Hypertension comorbidity DV	0.604	0.489	-0.0109*	0.004	-0.0150***	0.004	0.933***	0.008	0.916***	0.008
Obesity comorbidity DV	0.043	0.202	-0.014	0.010	-0.018	0.010	1.037*	0.018	1.039*	0.020
HRG1: EA14Z DV; CABG 1st	0.852	0.355	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
HRG2: EA25Z DV; Intermediate Congenital Surgery	0.017	0.131	0.0794***	0.022	0.0909***	0.021	0.916**	0.030	0.927*	0.031
HRG3: EA20Z DV; Other Complex Cardiac Surgery and Re-do's	0.012	0.109	-0.041	0.034	-0.039	0.033	1.107	0.060	1.081	0.054
HRG4: EA16Z DV; CABG 1st + PCI Pacing EP or RFA +/- Catheterisation	0.064	0.244	0.0487***	0.009	0.0542***	0.009	0.894***	0.016	0.872***	0.017
HRG5: Other non-reference HRG DV	0.055	0.227	-0.2933***	0.028	-0.2964***	0.028	1.112***	0.027	1.182***	0.031
Unstable Angina	0.072	0.259	-0.0210*	0.010	-0.0266**	0.010	0.977	0.015	1.002	0.016
Atrial Fibrillation	0.228	0.419	0.001	0.005	0.001	0.005	1.058***	0.011	1.041***	0.011
Acute myocardial infarction	0.078	0.268	-0.0326**	0.010	-0.0396***	0.010	1.015	0.017	1.033	0.017
Acute Renal Failure	0.014	0.117	0.037	0.024	0.039	0.024	1.173***	0.047	1.146**	0.050
Further CABG	0.802	0.399	-0.0139*	0.007			0.943***	0.011		
PTCA DV	0.008	0.091	-0.054	0.033			0.858**	0.042		
More than 1 vessel treated simultaneously	0.661	0.473	0.0096*	0.004			1.049***	0.009		
Valve Surgery on Heart	0.159	0.366	0.012	0.007			1.099***	0.016		
Multiple episode DV	0.226	0.418	-0.0290***	0.007			1.426***	0.019		
Mortality DV	0.025	0.158	-0.0449*	0.019			0.731***	0.036		
Adverse event DV	0.020	0.141	0.0619***	0.018			1.234***	0.039		
Infection DV: UTI	0.013	0.113	0.009	0.022			1.167***	0.039		
Infection DV: post-operative infection	0.028	0.166	0.0974***	0.013			1.623***	0.040		
Infection DV: C difficile	0.004	0.064	0.0820*	0.034			1.497***	0.082		
Constant			8.7620***	0.012	8.7549***	0.009	5.580***	0.104	5.068***	0.087
alpha							0.111***	0.003	0.135***	0.003
N			18875		18875		18875		18875	
r2_a / adjusted deviance r^2			0.52		0.517		0.626		0.57	

Exponentiated coefficients; DV: dummy variable; EP: electrophysiology; PCI: Percutaneous coronary intervention; PTCA: Percutaneous transluminal coronary angioplasty; RFA: radiofrequency ablation; UTI: urinary tract infection. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

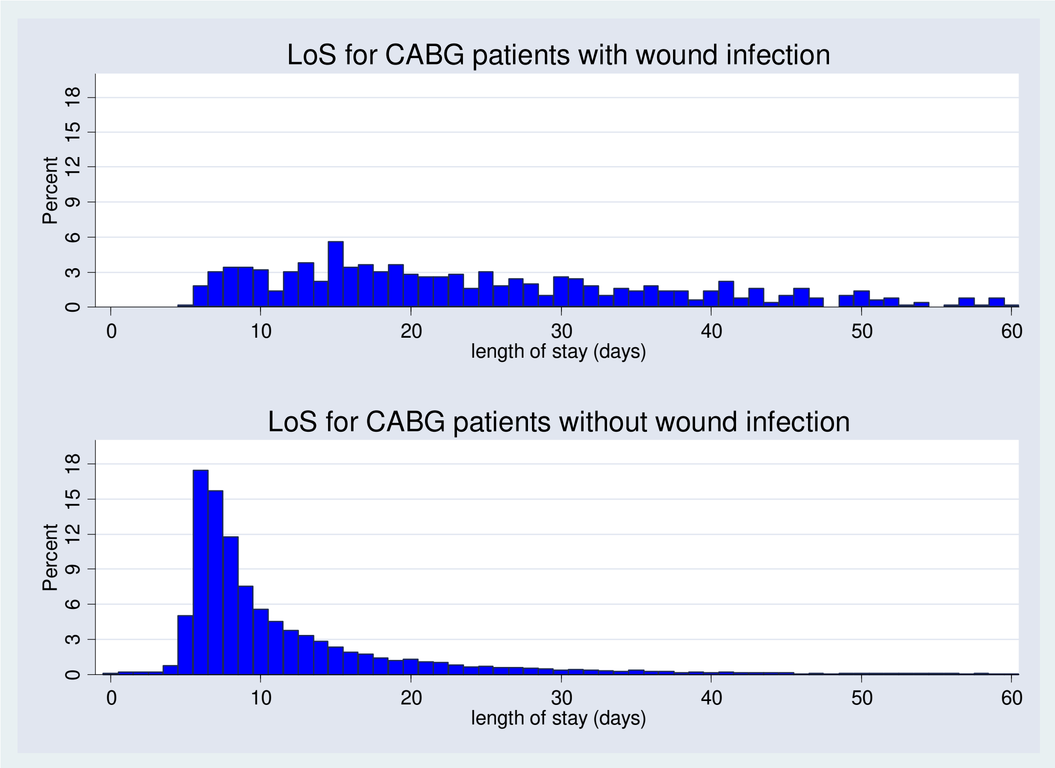

Figure 11: Variation in LoS by wound infection: CABG

Hospital performance

Only 28 hospitals provided CABG treatment. After adjusting for patient casemix, there was no correlation between average costs and LoS among these hospitals (r= -0.15, P=0.4407). LoS was particularly high in University Hospital Birmingham NHS Foundation Trust, as indicated by its position at the extreme of the LoS distribution, but it reported relatively low costs. In contrast, average LoS was lowest at the Cardiothoracic Centre - Liverpool NHS Trust but its costs were among the highest nationally for this treatment. Costs ranged from 10% below to 7% above the national mean, but LoS was more variable (32% below to 66% above).

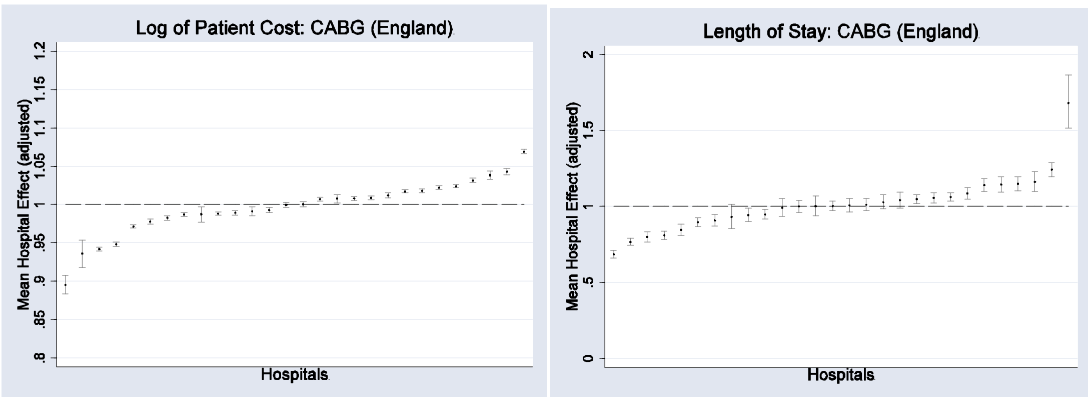

Figure 12: Hospital fixed effects: CABG

Box 13: Hospitals in top/bottom 10% by rank: CABG

cost rank	LoS rank	Hospital Name
1	11	University Hospitals Of Leicester NHS Trust
2	28	University Hospital Birmingham NHS Foundation Trust
3	13	The Newcastle Upon Tyne Hospitals NHS Foundation Trust
4	12	St George's Healthcare NHS Trust
25	1	The Cardiothoracic Centre - Liverpool NHS Trust
26	26	Blackpool, Fylde & Wyre Hospitals NHS Trust
27	16	Basildon & Thurrock University Hospitals NHS Foundation Trust
28	23	Leeds Teaching Hospitals NHS Trust

LoS rank	cost rank	Hospital Name
1	25	The Cardiothoracic Centre - Liverpool NHS Trust
2	11	Royal Brompton & Harefield NHS Trust
3	19	Plymouth Hospitals NHS Trust
4	18	King's College Hospital NHS Foundation Trust
25	22	Guy's & St Thomas' NHS Foundation Trust
26	26	Blackpool, Fylde & Wyre Hospitals NHS Trust
27	10	Barts & The London NHS Trust
28	2	University Hospital Birmingham NHS Foundation Trust

Inguinal hernia repair

Literature review

- Much of the research in the area of inguinal hernia has concentrated on the comparison between open and laparoscopic procedures
    - Kuhry et al., (2007) conducted a systematic review of randomised trials comparing total extraperitoneal (TEP) with open mesh or sutured repair. The review included 4,231 patients from 23 trials. In 10 of 15 trials that assessed time in theatre, TEP repair was associated with significantly (P<0.05) longer surgery time than open repair. A shorter postoperative hospital stay after TEP repair than after open repair was reported in 6 of 11 trials. Hospital costs were significantly higher for TEP than for open repair.
    - McCormack et al., (2005) conducted a systematic review of the effectiveness and cost-effectiveness of laparoscopic procedures for treating inguinal hernia. Thirty-seven RCTs and quasi-RCTs met the inclusion criteria on effectiveness and 14 economic evaluations were reviewed. Relative to open repair, laparoscopic repair was found to cost about £300-350 more per patient.
- Researchers on the EuroDRG project used individual patient level data to analyse the cost and LoS drivers for the treatment of inguinal hernia in ten countries (O' Reilly et al., 2012).
    - They found that costs and LoS increased with age.
    - A higher number of diagnoses and procedures led to higher costs and longer lengths of stay.
    - Compared to elective patients, emergency cases had statistically higher costs and LoS in almost all countries.
    - Having a principal diagnosis of bilateral inguinal hernia (without obstruction or gangrene) resulted in significantly higher costs and longer lengths of stay when compared to the reference case - an uncomplicated principal diagnosis of unilateral/unspecified inguinal hernia.
    - Costs were higher still for those hernia patients with obstruction or gangrene.
    - Having a laparoscopic procedure rather than open surgery significantly reduced LoS in Ireland and Austria but increased costs in five of the seven countries that analysed cost data.

Patient-level analysis

Results from our analyses of the costs and LoS for the 64,155 patients who had an inguinal hernia repair in 151 hospitals during 2007/8 are reported in Table 10. The mean cost of hernia repair amounts to £1,221 and average LoS is less than one day, the majority of such patients being treated on a day case basis. Significant (P<0.001) variables that explain cost and LoS are highlighted in Box 14.

Table 10: Cost and LoS in inguinal hernia patients: patient-level analysis

Explanatory variable	mean	sd	**Log of cost**				**LoS #**			
			Full Model		*Partial Model*		*Full Model*		*Partial Model*	
			β	se	β	se	β	se	β	se
Age 1: 1 to 42	0.203	0.402	-0.016***	0.004	-0.017***	0.004	0.820***	0.021	0.820***	0.021
Age 2: 43 to 56	0.197	0.398	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Age 3: 57 to 65	0.206	0.404	0.017***	0.004	0.017***	0.004	1.206***	0.027	1.211***	0.027
Age 4: 66 to 74	0.196	0.397	0.060***	0.004	0.060***	0.004	1.693***	0.037	1.701***	0.037
Age 5: 75+	0.199	0.399	0.114***	0.004	0.114***	0.004	2.389***	0.05	2.422***	0.051
Gender	0.925	0.264	-0.021***	0.005	-0.021***	0.005	0.888***	0.02	0.888***	0.02
Socioeconomic status	0.147	0.113	0.063***	0.012	0.061***	0.012	1.748***	0.105	1.738***	0.105
Emergency admission DV	0.042	0.201	0.477***	0.01	0.484***	0.010	4.125***	0.108	4.502***	0.116
Transfer-in DV	0.003	0.056	-0.05	0.032	-0.045	0.032	1.300***	0.1	1.325***	0.100
Transfer-out DV	0.003	0.051	0.061*	0.031	0.069*	0.031	1.599***	0.164	1.738***	0.165
Total number diagnoses	1.921	1.430	0.036***	0.002	0.036***	0.002	1.247***	0.008	1.265***	0.008
Total number procedures	2.315	0.669	0.003	0.003	0.011***	0.002	1.105***	0.014	1.104***	0.013
One non-severe Charlson comorbidity	0.105	0.307	-0.004	0.006	-0.003	0.006	0.937**	0.022	0.926**	0.022
At least 1 severe or 2 non-severe Charlson comorbidities	0.027	0.163	0.012	0.01	0.012	0.010	0.918*	0.032	0.907**	0.032
Hypertension comorbidity	0.163	0.370	-0.017***	0.004	-0.016***	0.004	0.898***	0.017	0.881***	0.017
Obesity comorbidity	0.002	0.048	0.034	0.035	0.034	0.035	1.03	0.099	1.012	0.096
HRG1: FZ18C DV; Inguinal Umbilical or Femoral Hernia Repairs >18 w/o cc	0.852	0.355	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
HRG2: FZ18D DV; Inguinal Umbilical or Femoral Hernia Repairs <19	0.023	0.148	-0.195***	0.012	-0.185***	0.012	0.472***	0.038	0.501***	0.039
HRG3: FZ18B DV; Inguinal Umbilical or Femoral Hernia Repairs >18 w icc	0.052	*0.221*	0.028***	0.008	0.027***	0.008	1.415***	0.042	1.411***	0.043
HRG4: FZ18A DV; Inguinal Umbilical or Femoral Hernia Repairs >18 w mcc	0.061	0.240	*0.082****	*0.007*	*0.082****	*0.007*	*1.187****	*0.031*	*1.188****	*0.032*
HRG5: Other non-reference HRG DV	0.013	0.113	0.202***	0.02	0.203***	0.02	1.571***	0.078	1.731***	0.083
Bilateral inguinal hernia, without obstruction or gangrene	0.083	0.276	0.083***	0.004	0.087***	0.004	1.668***	0.033	1.636***	0.032
Other inguinal hernia diagnoses	0.028	0.164	0.042***	0.011	0.044***	0.011	1.038	0.034	1.056	0.034
Connective tissue disorders	0.029	0.167	-0.016*	0.008	-0.016	0.008	0.852***	0.029	0.845***	0.030
Laparoscopy DV	0.162	0.369	0.021***	0.005			0.907***	0.021		
Failed laparoscopy DV	0.004	0.063	0.076***	0.017			1.486***	0.106		
With implants	0.846	0.361	-0.027***	0.004			0.849***	0.015		
Multiple episode DV	0.012	0.110	0.059***	0.016			1.717***	0.085		
Mortality DV	0.001	0.030	-0.117	0.086			0.541**	0.106		
Adverse event DV	0.001	0.035	-0.038	0.055			0.953	0.182		
Infection DV: UTI	0.001	0.031	0.064	0.056			1.132	0.149		
Infection DV: post-operative infection	0.000	0.022	-0.002	0.093			2.625***	0.658		
Infection DV: C difficile	0.000	0.012	0.317	0.18			3.386**	1.29		
Constant			6.894***	0.009	6.857***	0.008	0.202***	0.009	0.171***	0.007
alpha							0.369***	0.013	0.385***	0.014
N			64155		64155		64155		64155	
r2_a / adjusted deviance r^2			0.575		0.574		0.417		0.410	

Exponentiated coefficients; DV: dummy variable; w: with; w/o: without; cc: complications and comorbidities; icc: intermediate cc; mcc: major cc; UTI: urinary tract infection.

* p < 0.05, ** p < 0.01, *** p < 0.001

Box 14: Patient characteristics that are significant explanators of variations in cost or LOS for Inguinal hernia repair

Variables	Our Findings
Dependent variables (mean)	Cost – £1,221 LoS – 0.7
Demographics	When assessed at the 0.1% level of significance, older patients had higher costs and longer LoS than younger patients Male patients had 2% lower costs and 11% shorter LoS than females. Patients from poorer areas had higher costs and longer LoS.
Admission/ Discharge	Among the 4% of patients treated as emergencies, costs were 61% higher and LoS 4 times longer, the latter amounting to 3 additional days (compared to an average stay of less than 1 day). Transferred patients stayed longer than patients treated in a single hospital. Patients had 6% higher costs and 72% longer LoS when they were cared for by more than one consultant during their stay.
Case Complexity	A higher number of diagnoses was associated with higher patient cost and longer LoS. LoS was also higher when more procedures were performed. Patients diagnosed with hypertension had 2% lower costs and 10% shorter LoS.
HRGs	Relative to the reference HRG (Inguinal Umbilical or Femoral Hernia Repairs >18 without complications; FZ18C), the 2% of patients aged under 19 had 18% lower costs and 53% shorter LoS. Of patients aged over 18, those with intermediate complications (FZ18B) stayed 41% longer than those without complications and cost 3% more. Patients with major complications (FZ18A) cost 9% more and stayed 19% longer than the reference group.
Treatment Specific	Patient cost increased in patients diagnosed with bilateral hernia or with inguinal hernia with obstruction or gangrene, and also when a laparoscopic procedure was used. LoS was higher if a laparoscopic approach was used, but failed. However, where laparoscopic procedures were successful, patient LoS was 9% shorter.The use of implants was associated with lower patient cost (3%) and shorter LoS (15%). Patients diagnosed with connective tissue disorders had 15% shorter LoS.
Quality	LoS was 163% longer on average among the small proportion (<0.1%) of patients diagnosed with a post operative infection. The distribution of LoS for patients with and without wound infection is shown in Figure 13.

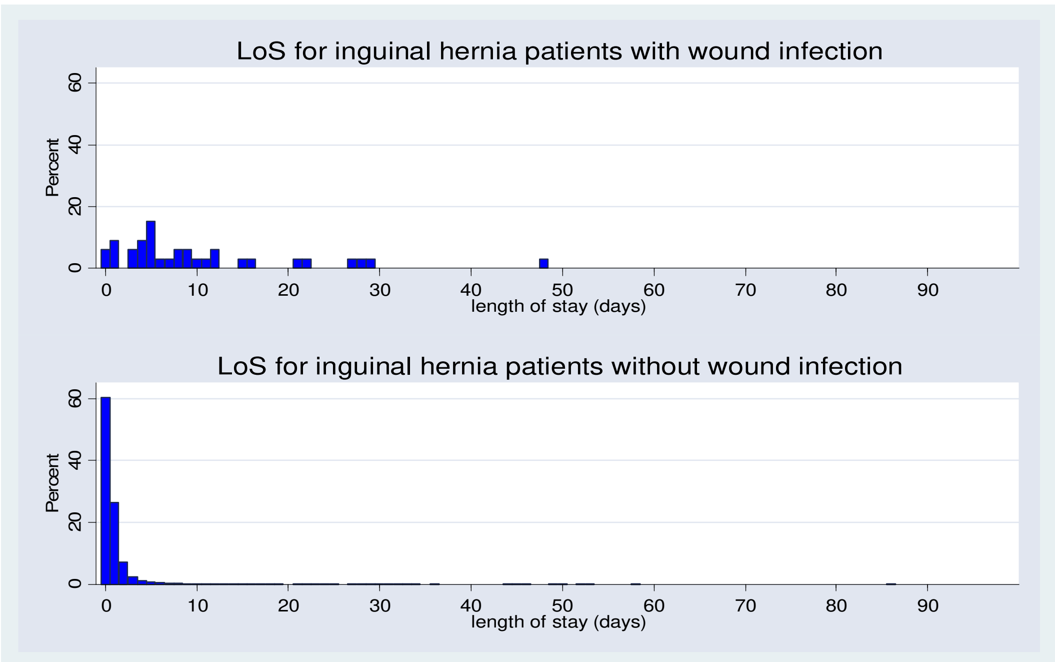

Figure 13: Variation in LoS by wound infection: inguinal hernia

Hospital performance

One hundred and fifty-one hospitals in our study undertook inguinal hernia repair. After adjusting for casemix differences, average hospital costs varied from 13% below the national mean to 9% above. In contrast, hospitals' mean LoS ranged widely, from 86% below to 136% above the national hospital mean. In other words, the difference in average LoS across these hospitals was more than two-fold, though this is not surprising given that mean LoS was only 0.7 days.

Unsurprisingly, given that 60% of patients are treated as day cases, the rank correlation between average costs and LoS was low (r=0.25; P=0.0021). Hospitals with the lowest average costs nationally did not have the shortest average LoS, and nor did a shorter average LoS correspond to lower average cost. At the other extreme, however, some hospitals had both high average costs and longer average LoS, notably Leeds Teaching Hospitals NHS Trust and Queen Elizabeth Hospital NHS Trust. One hospital on the left hand side of the LoS graph has very wide confidence intervals. This hospital, Sheffield Children's NHS Foundation Trust, treated only 10 patients of whom nine were day cases. The remaining patient had a LoS of one day.

In general, hospitals undertaking a higher total proportion of hernia cases had a significantly shorter average LoS, but no other hospital characteristics had a significant influence on either average costs or LoS.

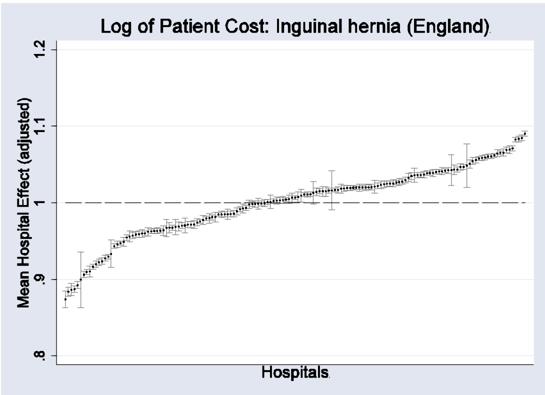

Figure 14: Hospital fixed effects: inguinal hernia

Box:15 Hospitals in top/bottom 5% by rank: inguinal hernia

cost rank	LoS rank	Hospital Name
1	133	Salford Royal NHS Foundation Trust
2	25	Worthing & Southlands Hospitals NHS Trust
3	90	Kingston Hospital NHS Trust
4	70	Poole Hospital NHS Trust
5	111	Southampton University Hospitals NHS Trust
6	28	Gloucestershire Hospitals NHS Foundation Trust
7	34	Royal Berkshire Hospital NHS Foundation Trust
8	53	Sherwood Forest Hospitals NHS Foundation Trust
144	125	Barking, Havering & Redbridge Hospitals NHS Trust
145	24	Nottingham University Hospitals NHS Trust
146	74	George Eliot Hospital NHS Trust
147	151	Queen Elizabeth Hospital NHS Trust
148	121	Mid Yorkshire Hospitals NHS Trust
149	148	Leeds Teaching Hospitals NHS Trust
150	18	West Suffolk Hospitals NHS Trust
151	96	The Hillingdon Hospital NHS Trust

LoS rank	cost rank	Hospital Name
1	47	The Royal Wolverhampton Hospitals NHS Trust
2	50	Queen Victoria Hospital NHS Foundation Trust
3	68	Royal Devon & Exeter NHS Foundation Trust
4	126	Weston Area Health NHS Trust
5	75	Hereford Hospitals NHS Trust
6	52	Hinchingbrooke Health Care NHS Trust
7	103	South Devon Healthcare NHS Foundation Trust
8	127	Sheffield Children’s NHS Foundation Trust
144	122	Sheffield Teaching Hospitals NHS Foundation Trust
145	94	Pennine Acute Hospitals NHS Trust
146	88	United Bristol Healthcare NHS Trust
147	70	Central Manchester & Manchester Children's University Hospitals NHS Trust
148	149	Leeds Teaching Hospitals NHS Trust
149	53	University Hospital Of South Manchester NHS Foundation Trust
150	91	Stockport NHS Foundation Trust
151	147	Queen Elizabeth Hospital NHS Trust

Hip replacement

Literature review

A number of studies have examined the impact of costs and LoS for hip replacement.

- Foote et al., (2009) analysed 675 consecutive patients who underwent primary total hip replacement in a regional orthopaedic centre in South West Britain.
  - The multivariate analysis used a logistic regression model with LoS as the dependent variable.
  - Those aged over 70 were found to be significantly more likely to stay over 2 weeks.
- Dall et al., (2009) in their multivariate analysis of predictors of LoS for patients with osteoarthritis also found that older patients stay longer in hospital.
- Cookson and Laudicella (2011) used English hospital records from 2001/2 to 2007/8 to assess the impact of income deprivation on LoS in patients undergoing hip replacement.
  - In 2001/2 after adjusting for casemix differences, patients from the most deprived areas stayed 6% longer than other patients. This difference fell to 2% longer by 2007/8
  - A higher number of diagnoses was associated with longer LoS
- Tien et al., (2009) identified the factors affecting hospital costs (charges) for hip procedures in Taiwan from 1996 to 2004.
  - Using multiple regression models to explain costs they found that patients younger than 65 years of age had lower costs than those 65+.
- Clement et al., (2011) conducted a study of Scottish patients. Using data from 2006-2008, they compared a prospectively selected group of patients aged $\geq$ 80 years with a group aged between 65 and 74 years having total hip replacement.
  - They found that on average the older group stayed approximately 3 days longer than those in the 65-74 age group ($P<0.0001$).
- The EuroDRG group carried out analysis on patient level data in 10 European countries to identify the explanators of cost and LoS for the treatment of hip replacement (Geissler et al., 2012).
  - They found that a significant positive relationship between age and LoS. The effect of age on costs is less clear
  - Men had a significantly shorter LoS than women
  - The higher the number of diagnoses and procedures, the higher the cost or longer the LoS
  - The revision of a hip implant leads to significantly longer LoS and higher costs in all countries

Patient-level analysis

During 2007/8, 82,902 patients had a hip replacement in 151 hospitals, the mean cost amounting to £5,499 and LoS to 12.3 days. Results from our analyses of differences among patients in their costs and LoS are reported in Table 11. Significant ($P<0.001$) variables that explain cost and LoS are highlighted in Box 16.

Table 11: Cost and LoS in hip replacement patients: patient-level analysis

			Log of cost				LoS #			
Explanatory variable	mean	sd	*Full Model*		*Partial Model*		*Full Model*		*Partial Model*	
			β	se	β	se	β	se	β	se
Age1: 1-63	0.208	0.406	-0.0080**	0.003	-0.0082**	0.003	0.922***	0.006	0.920***	0.006
Age2: 64-71	0.193	0.395	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Age3: 72-77	0.206	0.405	0.004	0.003	0.002	0.003	1.112***	0.007	1.116***	0.008
Age4: 78-83	0.189	0.391	0.0124***	0.003	0.0102***	0.003	1.265***	0.009	1.278***	0.010
Age5: 84+	0.204	0.403	0.0280***	0.004	0.0245***	0.004	1.385***	0.011	1.389***	0.012
Gender	0.339	0.473	0.002	0.002	0.000	0.002	0.950***	0.004	0.944***	0.005
Socioeconomic status	0.140	0.106	0.007	0.010	0.006	0.010	1.238***	0.028	1.239***	0.029
Emergency admission DV	0.367	0.482	0.0397***	0.009	-0.017	0.009	1.246***	0.019	1.357***	0.020
Transfer-in DV	0.032	0.175	-0.0302***	0.007	-0.0382***	0.007	1.042*	0.017	1.045**	0.017
Transfer-out DV	0.110	0.313	0.0320***	0.004	0.0319***	0.004	1.123***	0.010	1.161***	0.010
Total number diagnoses	4.071	2.837	0.0069***	0.001	0.0061***	0.001	1.066***	0.002	1.090***	0.002
Total number procedures	2.555	1.215	0.0214***	0.001	0.0164***	0.001	1.098***	0.003	1.108***	0.003
One non-severe Charlson comorbidity	0.220	0.414	0.004	0.002	0.003	0.002	1.020**	0.006	1.002	0.006
At least 1 severe or 2 non-severe Charlson comorbidities	0.100	0.300	0.000	0.004	-0.001	0.004	1.003	0.009	0.962***	0.009
Hypertension comorbidity DV	0.373	0.483	-0.0093***	0.002	-0.0093***	0.002	0.918***	0.005	0.908***	0.005
Obesity comorbidity DV	0.014	0.118	0.0153*	0.006	0.0157*	0.006	1.022	0.017	1.015	0.018
HRG1: HB12B DV; Major Hip Procedures for non Trauma Category 1 w cc	0.305	0.461	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
HRG2: HB14C DV; Intermediate Hip Procedures for non Trauma Category 1 w/o cc	0.014	0.117	-0.7731***	0.018	-0.7192***	0.018	0.467***	0.018	0.452***	0.018
HRG3: HB14B DV; Intermediate Hip Procedures for non Trauma Category 1 w cc	0.028	0.164	-0.5978***	0.014	-0.5433***	0.013	0.612***	0.017	0.585***	0.017
HRG4: HB12C DV; Major Hip Procedures for non Trauma Category 1 w/o cc	0.215	0.410	-0.0715***	0.003	-0.0737***	0.003	0.969***	0.006	0.997	0.007
HRG5: HB12A DV; Major Hip Procedures for non Trauma Category 1 w mcc	0.034	0.181	0.2291***	0.005	0.2334***	0.005	1.349***	0.017	1.371***	0.018
HRG6: HA13C DV; Intermediate Hip Procedures for Trauma w/o cc	0.028	0.165	-0.0839***	0.014	-0.1321***	0.013	1.090***	0.027	1.137***	0.025
HRG7: HA13B DV; Intermediate Hip Procedures for Trauma w icc	0.110	0.313	-0.021	0.013	-0.0692***	0.012	1.086***	0.023	1.108***	0.021
HRG8: HB11B DV; Major Hip Procedures for non Trauma Category 2 w cc	0.012	0.107	0.1301***	0.012	0.1140***	0.011	1.213***	0.030	1.184***	0.030
HRG9: HA13A DV; Intermediate Hip Procedures for Trauma w mcc	0.079	0.269	0.2003***	0.013	0.1661***	0.012	1.228***	0.027	1.268***	0.025
HRG10: VA04Z DV; Spine Hip Femur or Limb Procedures for Multiple Significant Trauma	0.014	0.119	0.0567***	0.015	0.022	0.014	1.143***	0.031	1.148***	0.029
HRG11: HA05Z DV; Reconstruction Procedures Category 2	0.039	0.193	0.1827***	0.008	0.1093***	0.006	1.252***	0.019	1.256***	0.016
HRG12: HA04C DV; Reconstruction Procedures Category 3 w/o cc	0.013	0.112	0.2820***	0.015	0.1323***	0.011	1.393***	0.039	1.404***	0.033
HRG13: HA12B DV; Major Hip Procedures Category 1 for Trauma w cc	0.033	0.179	0.1331***	0.012	0.1294***	0.012	1.217***	0.026	1.220***	0.026
HRG14: HA04B DV; Reconstruction Procedures Category 3 w cc	0.026	0.159	0.4714***	0.012	0.3288***	0.006	1.492***	0.033	1.466***	0.021
HRG15: Other non-reference HRG DV	0.051	0.220	-0.010	0.012	-0.0383**	0.012	1.369***	0.024	1.472***	0.026
Fracture of femur if main/secondary diagnosis = S72 or M84 or M96 or S324	0.295	0.456	0.0918***	0.011	0.1127***	0.011	1.130***	0.019	1.156***	0.020
Replacement of head of femur partial hip replacement	0.281	0.449	-0.0797***	0.009			1.093***	0.017		
Revision change or removal of hip replacement	0.085	0.279	-0.1591***	0.011			0.979	0.017		
Multiple episode DV	0.140	0.347	-0.0468***	0.004			1.413***	0.012		
Mortality DV	0.034	0.180	-0.010	0.007			0.761***	0.014		
Adverse event DV	0.012	0.109	0.0208*	0.010			1.085***	0.024		
Infection DV: UTI	0.036	0.185	0.0344***	0.006			1.151***	0.015		
Infection DV: post-operative infection	0.009	0.097	0.0647***	0.013			1.313***	0.028		
Infection DV: C difficile	0.007	0.085	0.0607***	0.015			1.554***	0.038		
Constant			8.4526***	0.004	8.4637***	0.004	4.124***	0.039	3.823***	0.036
alpha							0.203***	0.002	0.220***	0.002
N			82902		82902		82902		82902	
r2_a / adjusted deviance r^2			0.509		0.501		0.647		0.625	

Exponentiated coefficients; DV: dummy variable; w: with; w/o: without; cc: complications and comorbidities; icc: intermediate cc; mcc: major cc; UTI: urinary tract infection. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Box 16: Patient characteristics that are significant explanators of variations in cost or hip replacement

Variables	Our Findings
Dependent variables (mean)	Cost – £5,499 LoS – 12.3
Demographics	Patients aged over 77 had significantly higher costs than the reference group aged 64-71. LoS was positively associated with patient age. Female patients and patients living in poorer areas also had longer hospital stays.
Admission/ Discharge	Emergency cases cost 4% more and resulted in 25% longer stays. Transfers out cost 3% more and hospital stays were 12% longer. However, patients transferred in had 3% lower costs than patients treated in a single hospital. Patients cared for by more than one consultant had 5% lower costs but 41% longer LoS.
Case Complexity	Where a greater number of diagnoses or procedures was recorded, patient cost and LoS were higher, while a diagnosis of hypertension was associated with 1% lower costs and an 8% shorter LoS. If quality variables were not included, patients diagnosed with at least 2 non-severe, or one severe Charlson comorbidity, had 4% shorter LoS compared with patients without a diagnosed Charlson comorbidity. However, this variable was insignificant when quality was adjusted for.
HRGs	The range of circumstances in which a hip replacement procedure is performed is highlighted by the number of HRG dummy variables containing at least 1% of cases. Adjustments are made for the initial admission being due to trauma, categories of procedure, degree of complications and the inclusion of reconstruction. Relative to the reference HRG “Major Hip Procedures for non Trauma Category 1 with complications” (HB12B), the impact on cost of other specified HRGs ranged from 54% lower than the reference HRG (HB14C) to 60% higher (HA04B). The same HRGs had the largest impact on LoS, ranging from 53% lower than the reference HRG to 49% higher.
Treatment Specific	Patients diagnosed with a hip fracture had 10% higher costs and 13% longer LoS. Partial hip replacements were 8% cheaper but patients stayed 9% longer than full replacement cases. Costs were 15% lower for revision procedures.
Quality	In hospital mortality was associated with 24% shorter LoS. Patient costs and LoS were both higher when the patient was diagnosed with a UTI, post operative infection or C. difficile. LoS was also significantly longer when an adverse event occurred.

Hospital performance

After adjusting for casemix differences, there was less variation among hospitals in the average costs of hip replacement compared with other conditions, ranging from 7% below to 6% above the national average. The variation in average LoS was larger (from 36% below to 53% above the national mean). There was a low correlation between average costs and LoS (r=0.28; P=0.0004), which is partly a reflection of the limited variation in average costs. This low correlation explains why hospitals with low average costs did not necessarily have low average LoS. Nevertheless some hospitals appeared at the extreme upper end of both distributions, having both high costs and LoS. This is evident for Queen Elizabeth Hospital NHS Trust, St Helens & Knowsley Hospitals NHS Trust and Sheffield Teaching Hospitals NHS Foundation Trust.

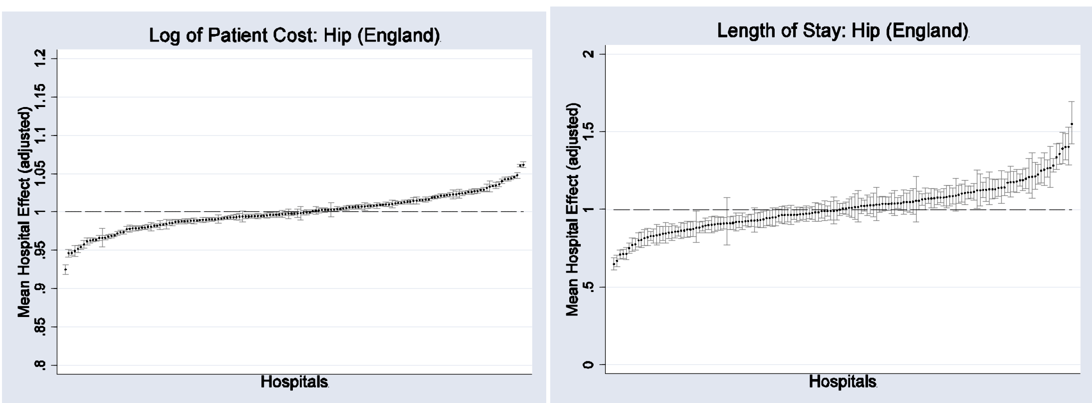

Figure 15: Hospital fixed effects: hip replacement

Box 17: Hospitals in top/bottom 5% by rank: hip replacement

cost rank	LoS rank	Hospital Name
1	86	The Royal Wolverhampton Hospitals NHS Trust
2	30	North Cheshire Hospitals NHS Trust
3	24	South Warwickshire General Hospitals NHS Trust
4	151	Queen Mary's Sidcup NHS Trust
5	83	Shrewsbury & Telford Hospital NHS Trust
6	11	Weston Area Health NHS Trust
7	95	Barts & The London NHS Trust
8	107	University Hospital Birmingham NHS Foundation Trust
144	100	North Cumbria Acute Hospitals NHS Trust
145	49	Gateshead Health NHS Foundation Trust
146	134	Whipps Cross University Hospital NHS Trust
147	93	Bromley Hospitals NHS Trust
148	54	Northern Lincolnshire & Goole Hospitals NHS Trust
149	150	St Helens & Knowsley Hospitals NHS Trust
150	27	Royal National Orthopaedic Hospital NHS Trust
151	146	Queen Elizabeth Hospital NHS Trust

LoS rank	cost rank	Hospital Name
1	27	West Suffolk Hospitals NHS Trust
2	83	Taunton & Somerset NHS Trust
3	38	Royal West Sussex NHS Trust
4	52	Northern Devon Healthcare NHS Trust
5	54	West Dorset General Hospitals NHS Trust
6	69	South Devon Healthcare NHS Foundation Trust
7	16	The Queen Elizabeth Hospital King's Lynn NHS Trust
8	47	Heatherwood & Wexham Park Hospitals NHS Trust
144	141	Sheffield Teaching Hospitals NHS Foundation Trust
145	59	Blackpool, Fylde & Wyre Hospitals NHS Trust
146	151	Queen Elizabeth Hospital NHS Trust
147	20	East & North Hertfordshire NHS Trust
148	130	St George's Healthcare NHS Trust
149	129	Central Manchester & Manchester Children's University Hospitals NHS Trust
150	149	St Helens & Knowsley Hospitals NHS Trust
151	4	Queen Mary's Sidcup NHS Trust

Knee replacement

Literature review

- Tien et al., (2009) explored the factors affecting hospital charges for knee procedures in Taiwan from 1996 to 2004.
  - Using multiple regression models to predict costs they found that patients younger than 65 years of age had lower costs than those equal to or over 65.
- Macario et al., (1997) analysed a random sample of 94 inpatients having knee replacement to determine whether the Charlson comorbidity index was a good predictor of hospital costs and LoS.
  - They found that the Charlson was a significant predictor of costs for knee replacement. A one unit increase in the Charlson comorbidity index score resulted in an estimated increase in hospital costs of $1,229 (P=0.003).
- Clement et al., (2011) collected prospective data on Scottish patients over the period 2006-2008, They compared a group of patients aged 80 or over with patients aged between 65 and 74 years having total knee replacement.
  - On average, the older group stayed approximately 2 days longer than the younger patients (P<0.0001).
- Research carried out by the EuroDRG group analysing the determinants of costs and LoS for the treatment of knee replacement across 10 countries (Chiarello et al., 2012) found
  - In general, the higher the number of diagnoses and procedures the higher the cost and longer the LoS
  - However, in England the total number of procedures was negatively associated with cost, perhaps because the cost impact was captured by HRGs
  - in most countries, revisions of the knee were significantly more costly while the effect on LoS was mixed
  - Patients transferred to other hospitals were significantly more costly in most countries.

Patient-level analysis

Data were available for 62,034 patients having a knee replacement in 147 hospitals. Results of our analyses of their costs and LoS are reported in Table 12. Patient characteristics that are significant (P<0.001) explanators of variations in cost or LoS are summarised in Box 18.

Box 18: Patient characteristics that are significant explanators of variations in knee replacement

Variables	Our Findings
Dependent variables (mean)	Cost – £4,452 LoS – 6.9
Demographics	Patients aged over 73 had higher costs than the reference age group 63-68. LoS increased with age. Female patients and patients from poorer areas had longer LoS.
Admission/ Discharge	Emergency spells were 48% longer than elective spells. Patients transferred to another hospital had 4% higher costs and 30% longer LoS. LoS was 16% longer for those transferred in, but this was no longer significant at the 0.1% level once quality was adjusted for. Patients cared for by more than one consultant stayed 61% longer than those who were under the care of a single consultant throughout their time in hospital.
Case Complexity	An additional diagnosis or procedure increased patient LoS. Patients diagnosed with hypertension had 7% shorter LoS.
HRGs	Relative to the base HRG "Major Knee Procedures for Non-Trauma cat 2 with complications" (HB21B), patient cost was 18% lower in the absence of complications (HB21C) but 39% higher when major complications occurred (HB21A). Patients categorised to "Reconstruction procedures category 1" (HA06Z), had the lowest costs, 23% lower than the reference group. The relationships between patient HRG and LoS moved in the same direction as those between HRG and cost, except that LoS was higher among patients having reconstruction.
Treatment Specific	The use of a revision procedure increased patient cost by 18% and LoS by 21%
Quality	Less than 1% of patients experienced infections or adverse events. For those that did, LoS was significantly longer in the presence of an adverse event (23%), UTI (14%), wound infection (31%) or C. difficile (50%).

Table 12: Cost and LoS in knee replacement patients: patient-level analysis

Explanatory variable	mean	sd	Log of cost				LoS #			
			Full Model		*Partial Model*		*Full Model*		*Partial Model*	
			β	se	β	se	β	se	β	se
Age 1: 1 to 62	0.226	0.418	-0.0035	0.003	-0.0041	0.003	0.960***	0.006	0.960***	0.006
Age 2: 63 to 68	0.203	0.402	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Age 3: 69 to 73	0.200	0.400	0.0048	0.003	0.0043	0.003	1.063***	0.007	1.064***	0.007
Age 4: 74 to 78	0.194	0.395	0.0099***	0.003	0.0098***	0.003	1.167***	0.008	1.168***	0.008
Age 5: 79+	0.178	0.383	0.0174***	0.003	0.0174***	0.003	1.337***	0.009	1.348***	0.01
Gender	0.421	0.494	-0.0063**	0.002	-0.0050*	0.002	0.933***	0.004	0.933***	0.004
Socioeconomic status	0.146	0.110	0.0215*	0.009	0.0197*	0.009	1.237***	0.026	1.240***	0.027
Emergency admission DV	0.008	0.090	0.0192	0.032	0.0374	0.033	1.477***	0.053	1.703***	0.062
Transfer-in DV	0.004	0.063	0.0163	0.025	0.0233	0.025	1.157**	0.052	1.157***	0.049
Transfer-out DV	0.024	0.153	0.0393***	0.008	0.0387***	0.008	1.298***	0.024	1.314***	0.025
Total number diagnoses	3.083	2.013	0.0021*	0.001	0.0047***	0.001	1.057***	0.002	1.075***	0.002
Total number procedures	2.377	0.938	-0.0037	0.002	-0.002	0.002	1.067***	0.004	1.084***	0.004
One non-severe Charlson comorbidity	0.201	0.400	0.0005	0.003	-0.0018	0.003	1.005	0.006	0.993	0.006
At least 1 severe or 2 non-severe Charlson comorbidities	0.050	0.217	0.0064	0.005	0.0008	0.005	1.037**	0.013	1.02	0.014
Hypertension comorbidity DV	0.418	0.493	-0.0029	0.003	-0.0064*	0.003	0.934***	0.006	0.922***	0.006
Obesity comorbidity DV	0.025	0.157	0.0094	0.005	0.005	0.005	1.011	0.013	0.995	0.013
HRG1: HB21B DV; Major Knee Procedures for non trauma cat 2 w cc	0.547	0.498	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
HRG2: HB21C DV; Major Knee Procedures for non trauma cat 2 w/o cc	0.348	0.476	-0.1992***	0.003	-0.1978***	0.003	0.962***	0.007	0.978**	0.007
HRG3: HA06Z DV; Reconstruction Procedures cat 1	0.027	0.162	-0.2644***	0.012	-0.2593***	0.013	1.376***	0.023	1.368***	0.023
HRG4: HB21A DV; Major Knee procedures for non trauma cat 2 w mcc	0.050	0.218	0.3302***	0.008	0.3337***	0.007	1.342***	0.018	1.398***	0.017
HRG5: Other non-reference HRG DV	0.028	0.164	-0.2943***	0.017	-0.2282***	0.017	1.040*	0.02	1.168***	0.024
Revision of knee replacement procedure	0.048	0.214	0.1643***	0.007			1.211***	0.016		
Procedure: transfusion of blood and blood components	0.005	0.069	-0.0282	0.015			1.023	0.03		
Multiple episode DV	0.030	0.170	0.0306**	0.01			1.605***	0.032		
Mortality DV	0.002	0.047	0.0153	0.038			0.837	0.08		
Adverse event DV	0.009	0.093	0.0243	0.019			1.232***	0.035		
Infection DV: UTI	0.006	0.075	0.027	0.025			1.135***	0.041		
Infection DV: post-operative infection	0.002	0.050	-0.0155	0.038			1.314***	0.072		
Infection DV: C difficile	0.001	0.026	0.0194	0.07			1.495***	0.139		
Constant			8.3673***	0.006	8.3637***	0.006	4.265***	0.052	4.000***	0.051
alpha							0.083***	0.002	0.092***	0.002
N			62034		62034		62034		62034	
r2_a / adjusted deviance r^2			0.723		0.718		0.435		0.408	

Exponentiated coefficients; DV: dummy variable; w: with; w/o: without; cc: complications and comorbidities; mcc: major cc; UTI: urinary tract infection.

* p < 0.05, ** p < 0.01, *** p < 0.001

Hospital performance

The variation among hospitals in the average costs of knee replacement ranged from 14% below to 10% above the national average, which was narrower than the variation in LoS (from 52% below to 82% above the national mean LoS). Compared to hip replacement, there was a weaker correlation between average costs and LoS (r=0.18; P=0.0325). This relationship was also apparent in the extremes of the distributions. For instance, Kingston Hospital NHS Trust and Weston Area Health NHS Trust were among the hospitals with the lowest costs and shortest LoS nationally. At the other end of the scale, a number of hospitals had higher costs and longer LoS, noticeably Queen Elizabeth Hospital NHS Trust, Newham University Hospital NHS Trust, St Helens & Knowsley Hospitals NHS Trust, Airedale NHS Trust and The Lewisham Hospital NHS Trust.

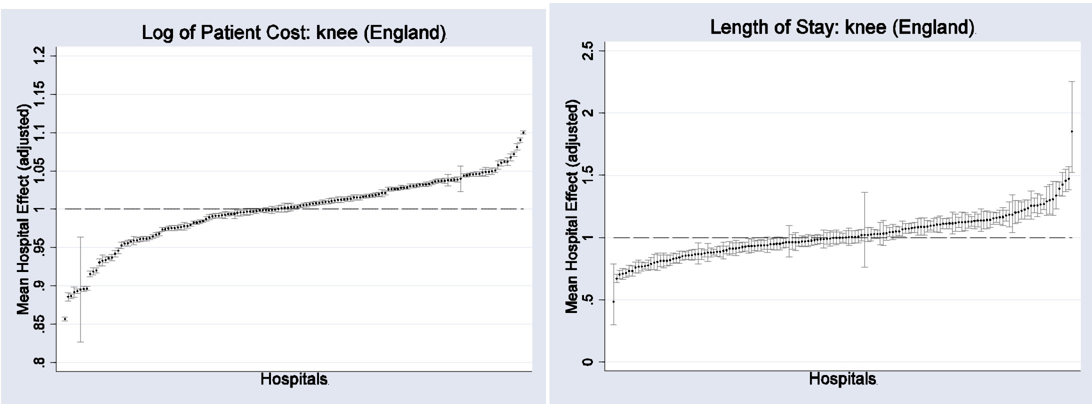

Figure 16: Hospital fixed effects: knee replacement

Box 19: Hospitals in top/bottom 5% by rank: knee replacement

cost rank	LoS rank	Hospital Name
1	100	Shrewsbury & Telford Hospital NHS Trust
2	67	Blackpool, Fylde & Wyre Hospitals NHS Trust
3	51	The Royal Orthopaedic Hospital NHS Foundation Trust
4	60	North Cheshire Hospitals NHS Trust
5	136	North Hampshire Hospitals NHS Trust
6	1	Kingston Hospital NHS Trust
7	4	Weston Area Health NHS Trust
141	138	Airedale NHS Trust
142	146	St Helens & Knowsley Hospitals NHS Trust
143	141	Newham University Hospital NHS Trust
144	73	Salford Royal NHS Foundation Trust
145	36	Lancashire Teaching Hospitals NHS Foundation Trust
146	75	Nuffield Orthopaedic Centre NHS Trust
147	145	Queen Elizabeth Hospital NHS Trust

LoS rank	cost rank	Hospital Name
1	6	Kingston Hospital NHS Trust
2	93	West Suffolk Hospitals NHS Trust
3	134	Gateshead Health NHS Foundation Trust
4	7	Weston Area Health NHS Trust
5	112	Worthing & Southlands Hospitals NHS Trust
6	57	The Queen Elizabeth Hospital King's Lynn NHS Trust
7	17	South Warwickshire General Hospitals NHS Trust
141	143	Newham University Hospital NHS Trust
142	133	The Lewisham Hospital NHS Trust
143	125	Kettering General Hospital NHS Trust
144	69	Central Manchester & Manchester Children's University Hospitals NHS Trust
145	147	Queen Elizabeth Hospital NHS Trust
146	142	St Helens & Knowsley Hospitals NHS Trust
147	127	St George's Healthcare NHS Trust

Stroke (ischemic and haemorrhagic)

Literature review

- Reed et al., (2001) estimated inpatient costs, LoS, and in-hospital mortality for patients with subarachnoid haemorrhage (SAH), intra-cerebral haemorrhage (ICH), ischemic cerebral infarction (ICI), and transient ischemic attack (TIA) treated in US community hospitals.
    - Multivariate statistical techniques were used on patient level data to examine patient, hospital and outcome-related factors associated with inpatient costs.
    - They found that costs decreased with age.
- The EuroDRG partners used a hierarchical approach to measure the cost and LoS effects for the treatment of stroke across Europe (Peltola, 2012).
    - They found a linear relationship between age and LoS – the older the patient the longer was the stay.
    - The more diagnoses and procedures, the longer was LoS and the higher were costs.
    - Patients transferred to another hospital had significantly longer LoS in almost all countries
    - Mortality significantly shortened LoS and was generally associated with lower costs.
    - Contracting pneumonia significantly increased LoS and costs.

Patient-level analysis

In Table 13 we report results from our analyses of the costs and LoS for the 69,372 patients who suffered a stroke and were treated in one of 149 hospitals during 2007/8. The mean cost of their care amounted to £3,002, but these patients tended to have long hospital stays: mean LoS amounted to 20.2 days. Patient characteristics that proved to be significant (P<0.001) explanators of cost and LoS are summarised in Box 20 below.

Box 20: Patient characteristics that are significant expanators of variations in cost or LOS for stroke

Variables	Our Findings
Dependent variables (mean)	Cost – £3,002 LoS – 20.2
Demographics	When assessed at the 0.1% level, older patients had higher costs and longer LoS. LoS was also higher among female patients.
Admission/ Discharge	Patients transferred between hospitals had higher costs and LoS than patients treated in a single hospital. Patients admitted as emergencies had 23% shorter LoS than elective cases. 68% of stroke patients were cared for by more than one consultant during their time in hospital. These patients were 29% more costly and stayed 58% longer than those under the care of a single consultant.
Case Complexity	Patients with a higher number of diagnoses or procedures had higher costs and LoS. Patients diagnosed with Charlson comorbidities had significantly shorter stays. This impact was larger if the patient was diagnosed with 2 or more non-severe or a severe Charlson comorbidity. Cost was also lower (by 4%) in patients diagnosed with 2 or more non-severe Charlson comorbidities or at least 1 major comorbidity. A recorded diagnosis of hypertension was associated with 7% lower LoS.
HRGs	Patients categorised into (AA23Z) "Haemorrhagic Cerebrovascular Disorders" had 19% lower costs than the reference HRG (AA22Z) "Non-Transient Stroke or Cerebrovascular Accident or Nervous System Infection", but there was no significant difference in LoS.
Treatment Specific	A diagnosis of cerebral haemorrhage was associated with a 10% increase in patient cost, relative to the base case of infarction. LoS was shorter when patients suffered an intracerebral haemorrhage, but the statistical significance of this finding was sensitive to whether or not quality was accounted for. Patients diagnosed with an unspecified stroke had 6% lower costs and 19% shorter LoS than infarction cases. A diagnosis of pneumonia, hemiplegia or paraplegia was associated with increased patient cost and LoS.
Quality	Mortality was associated with 11% lower costs and 29% shorter LoS (Figure 17); the occurrence of an adverse event, UTI or C. difficile infection increased patient cost. Two percent of patients suffered C. difficile, and their costs were higher by 39% and LoS was almost doubled on average (96% longer).

Table 13: Cost and LoS in stroke patients: patient-level analysis

Explanatory variable	mean	sd	Log of cost				LoS #			
			Full Model		*Partial Model*		*Full Model*		*Partial Model*	
			β	se	β	se	β	se	β	se
Age 1: <66	0.209	0.407	-0.057***	0.008	-0.065***	0.008	0.858***	0.013	0.853***	0.013
Age 2: 66-74	0.189	0.391	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*0.000*
Age 3: 75-81	0.230	0.421	0.045***	0.007	0.039***	0.007	1.115***	0.015	1.089***	0.014
Age 4: 82-86	0.187	0.390	0.076***	0.007	0.070***	0.007	1.212***	0.017	1.170***	0.016
Age 5: 87+	0.185	0.388	0.075***	0.007	0.061***	0.008	1.252***	0.018	1.173***	0.016
Gender	0.475	0.499	-0.013**	0.005	-0.014**	0.005	0.934***	0.008	0.930***	0.008
Socioeconomic status	0.162	0.120	0.011	0.021	0.011	0.021	1.136**	0.045	1.128**	0.045
Emergency admission DV	0.955	0.207	0.004	0.019	0.039*	0.019	0.774***	0.020	0.814***	0.022
Transfer-in DV	0.084	0.278	0.179***	0.013	0.161***	0.013	1.253***	0.027	1.212***	0.027
Transfer-out DV	0.197	0.398	0.128***	0.006	0.178***	0.006	1.574***	0.016	1.756***	0.016
Total number diagnoses	5.652	3.260	0.026***	0.001	0.041***	0.001	1.104***	0.002	1.139***	0.002
Total number procedures	2.087	1.680	0.042***	0.002	0.058***	0.002	1.078***	0.003	1.107***	0.003
One non-severe Charlson comorbidity	0.272	0.445	-0.010	0.005	-0.025***	0.005	0.965***	0.010	0.925***	0.009
At least 1 severe or 2 non-severe Charlson comorbidities	0.166	0.372	-0.041***	0.007	-0.078***	0.007	0.873***	0.011	0.797***	0.010
Hypertension comorbidity DV	0.477	0.499	-0.003	0.005	-0.011*	0.005	0.933***	0.008	0.915***	0.008
Obesity comorbidity DV	0.007	0.082	-0.031	0.028	-0.051	0.029	0.895*	0.044	0.880*	0.045
HRG1: AA22Z DV; Non-Transient Stroke or Cerebrovascular Accident Nervous system infection	0.799	0.401	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
HRG2: AA23Z DV; Haemorrhagic Cerebrovascular Disorders	0.122	0.328	-0.212***	0.027	-0.194***	0.027	1.028	0.039	1.080	0.044
Other non-reference HRG DV	0.079	0.270	0.021	0.012	0.010	0.012	0.992	0.016	0.970	0.016
Intracerebral haemorrhage	0.138	0.345	0.101***	0.026	0.036	0.025	0.943	0.034	0.867***	0.033
Unspecified Stroke	0.246	0.431	-0.067***	0.005	-0.088***	0.006	0.806***	0.009	0.789***	0.009
Pneumonia	0.098	0.297	0.110***	0.008	0.071***	0.007	1.309***	0.018	1.171***	0.015
Secondary diagnosis: Hemiplegia or paraplegia	0.067	0.249	0.081***	0.009	0.081***	0.009	1.250***	0.021	1.229***	0.020
Multiple episode DV	0.638	0.481	0.255***	0.006			1.576***	0.017		
Mortality DV	0.240	0.427	-0.112***	0.006			0.713***	0.009		
Adverse event DV	0.031	0.174	0.105***	0.013			1.362***	0.028		
Infection DV: UTI	0.090	0.286	0.115***	0.008			1.360***	0.018		
Infection DV: post-operative infection	0.002	0.039	0.108	0.062			1.293**	0.103		
Infection DV: C difficile	0.018	0.134	0.330***	0.018			1.959***	0.046		
Constant			7.353***	0.022	7.388***	0.022	7.010***	0.225	7.599***	0.245
alpha							0.799***	0.005	0.863***	0.005
N			69372		69372		69372		69372	
r2_a / adjusted deviance r^2			0.351		0.318		0.329		0.279	

Exponentiated coefficients; DV: dummy variable; UTI: urinary tract infection.

* p < 0.05, ** p < 0.01, *** p < 0.001

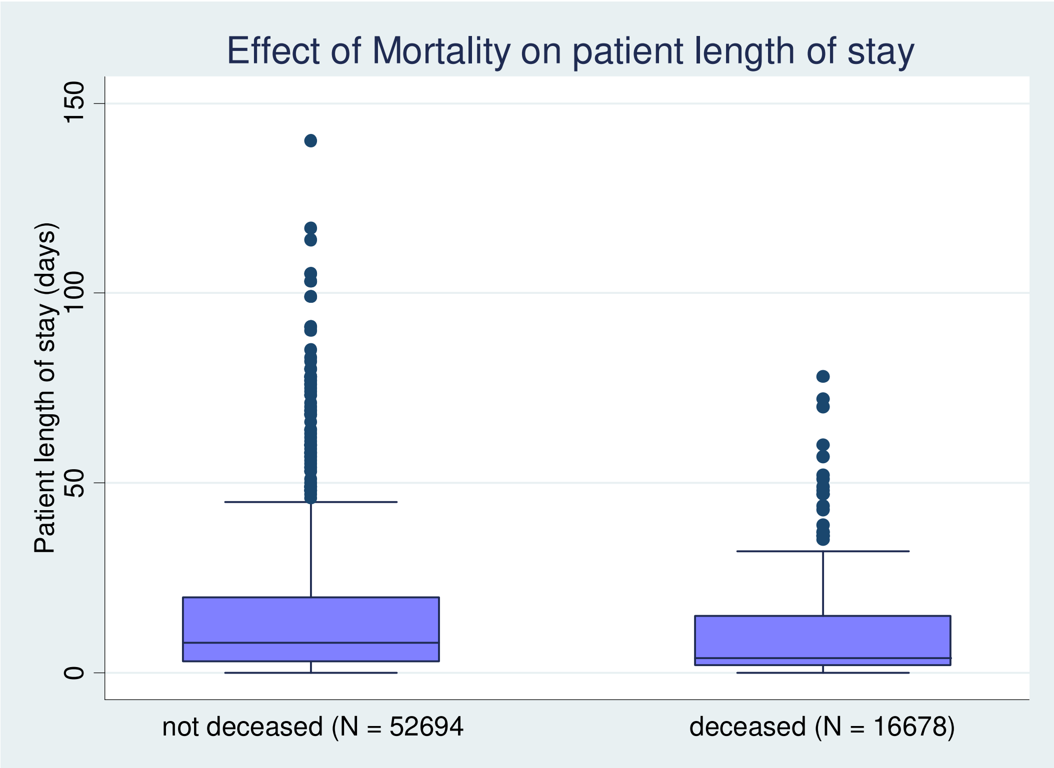

Figure 17: Variation in LoS by mortality: stroke

Hospital performance

After adjusting for casemix differences, average hospital costs ranged from 29% below to 12% above the national average; the corresponding figures for LoS were 92% to 202%. Of the 10 conditions we analysed, the variation in LoS was greatest for stroke, equating to a three-fold difference between the most efficient and least efficient hospitals (Figure 18).

There was a relatively strong positive relationship between average costs and LoS with r=0.41 (P<0.001). Some hospitals had both the lowest costs and LoS nationally, notably Royal Devon & Exeter NHS Foundation Trust, Great Ormond Street Hospital for Children NHS Trust and Countess of Chester Hospital NHS Foundation Trust. Great Ormond Street Hospital is identifiable on the cost graph by its large confidence interval. Unsurprisingly, this hospital treated very few cases compared with the other hospitals in the analysis. This helps explain the uncertainty around the estimate of mean cost.

At the other extreme, those with very high average LoS also tended to have very high average costs, with the following hospitals performing poorly whichever resource measure was used: The Rotherham NHS Foundation Trust, Queen Mary's Sidcup NHS Trust, Mid Yorkshire Hospitals NHS Trust, and Sheffield Teaching Hospitals NHS Foundation Trust. Hospitals with higher LoS also tended to have a higher mortality rates for stroke patients. The hospital on the extreme right hand side of the LoS graph is Queen Mary's Sidcup. The reason for this hospital’s extremely high average LoS is unclear, but a possible explanation is that there is an onsite rehabilitation unit.

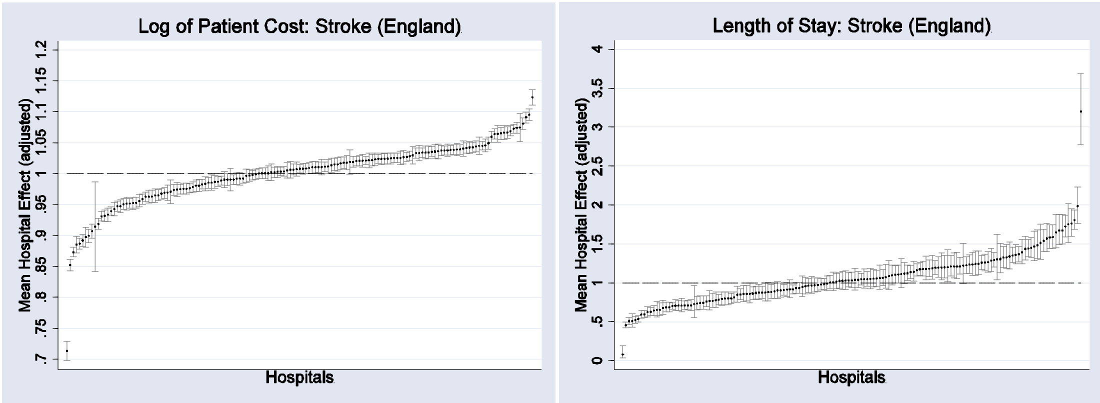

Figure 18: Hospital fixed effects: Stroke

Box 21: Hospitals in top/bottom 5% by rank: stroke

cost rank	LoS rank	Hospital Name
1	138	Blackpool, Fylde & Wyre Hospitals NHS Trust
2	53	Southend University Hospital NHS Foundation Trust
3	7	Royal Devon & Exeter NHS Foundation Trust
4	93	Newham University Hospital NHS Trust
5	45	Dudley Group Of Hospitals NHS Trust
6	51	Derby Hospitals NHS Foundation Trust
7	19	Homerton University Hospital NHS Foundation Trust
143	113	Queen Elizabeth Hospital NHS Trust
144	66	The Hillingdon Hospital NHS Trust
145	91	Bedford Hospital NHS Trust
146	147	Mid Yorkshire Hospitals NHS Trust
147	136	Wrightington, Wigan & Leigh NHS Trust
148	134	Harrogate & District NHS Foundation Trust
149	149	Queen Mary's Sidcup NHS Trust

LoS rank	cost rank	Hospital Name
1	9	Great Ormond Street Hospital For Children NHS Trust
2	31	South Devon Healthcare NHS Foundation Trust
3	26	Royal West Sussex NHS Trust
4	12	Countess Of Chester Hospital NHS Foundation Trust
5	64	The Newcastle Upon Tyne Hospitals NHS Foundation Trust
6	136	St George's Healthcare NHS Trust
7	3	Royal Devon & Exeter NHS Foundation Trust
143	141	The Rotherham NHS Foundation Trust
144	140	Sheffield Teaching Hospitals NHS Foundation Trust
145	45	Calderdale & Huddersfield NHS Foundation Trust
146	114	Central Manchester & Manchester Children's University Hospitals NHS Trust
147	146	Mid Yorkshire Hospitals NHS Trust
148	111	The Royal Bournemouth & Christchurch Hospitals NHS Foundation Trust
149	149	Queen Mary's Sidcup NHS Trust

Performance within and across hospitals

We now assess whether the hospital effects were correlated across treatments. Having accounted for the influence of patient characteristics, these effects capture the hospital's influence on resource use. Thus, a higher hospital effect indicates higher resource use among this hospital's patients than similar patients treated at other hospitals (Dormont and Milcent, 2004; Olsen and Street, 2008; Street et al., 2012). As a consequence, these hospital effects can be interpreted as measures of relative efficiency in managing costs or LoS.

As we ran separate regressions using log of cost and LoS for each of the 10 treatments, each of our 164 hospitals had a set of no more than 10 rankings for cost and up to 10 rankings for LoS. We rescaled the rankings in order to make them comparable across treatments. For each treatment, the bottom ranking hospital received a rank of 1 and the others received a value between 0 and 1 according to their relative positions. Therefore, the hospital ranked 28^{th} in the CABG analysis had an adjusted ranking of 1; and the hospital ranked 28^{th} in the appendectomy analysis had an adjusted ranking of 0.185 (=28/151).

We plotted the mean (rescaled) rankings for all 164 hospitals, to see whether any correlations across the conditions were apparent (Figure 19 and Figure 20). Only 28 hospitals undertook CABG, so there are comparatively few data points. The following relationships are apparent:

- The rankings for cholecystectomy were directly correlated with those of hernia. For these two treatments, the correlation coefficient was 0.72 for the cost ranking and 0.59 in the LoS analysis. Both these coefficients were statistically significant at the 5% level (using the Bonferroni adjustment)(Bland and Altman, 1995).
- In the LoS analysis, there was a positive correlation between hospital ranking for appendectomy and cholecystectomy (r=0.54) but the correlation between these two treatments was not statistically significant in the cost rankings (r=0.21; P = 0.4436).
- Rankings for hip and knee replacement were also significantly correlated (costs: r=0.54; LoS: r=0.71).
- No other statistically significant correlations were found.

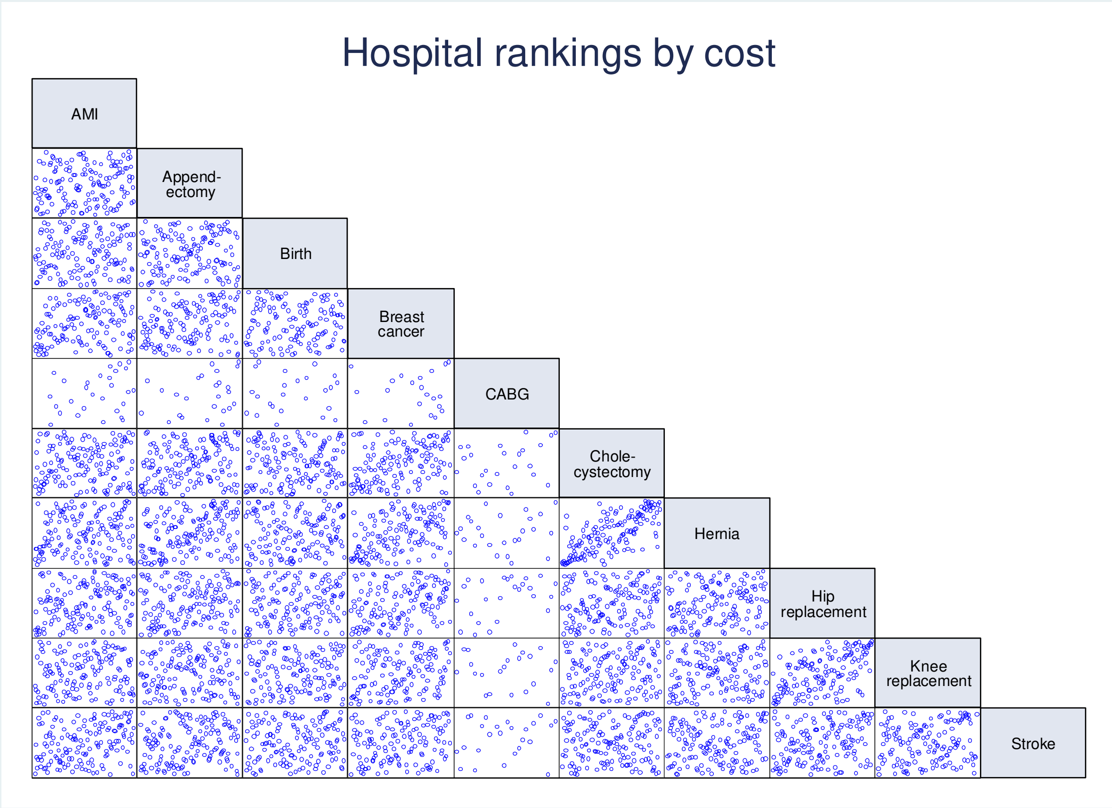

Figure 19: Efficiency rankings by cost: 164 hospitals across 10 types of treatment

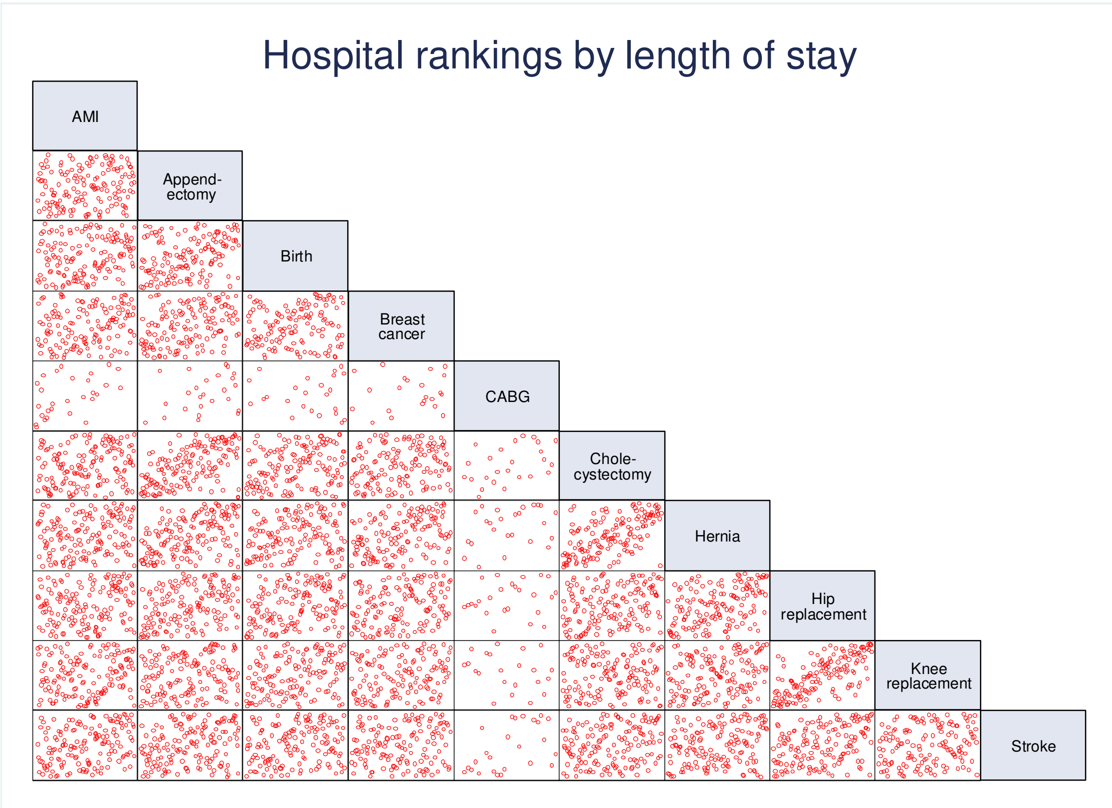

Figure 20: Efficiency rankings by LoS: 164 hospitals across 10 types of treatment

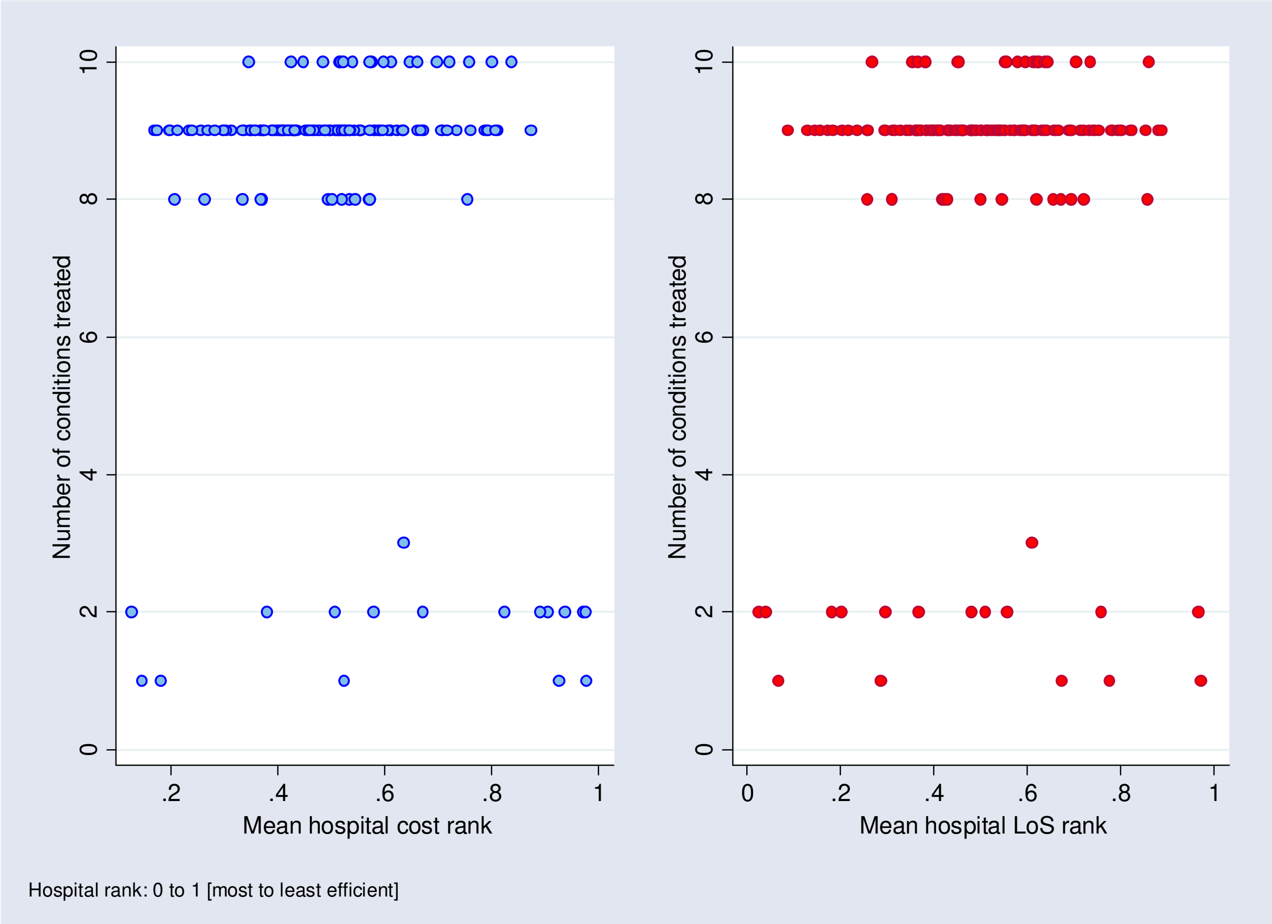

Figure 21: Scatterplot showing hospital efficiency rank by number of types of treatment provided

We then explored the relationship between the number of treatments undertaken by a hospital and the hospital's position within the distribution. Figure 21 plots the average rank for each hospital by the number of conditions they treat. Rankings for cost are on the left, and LoS ranks are shown on the right hand side of the figure. The x-axis shows the mean hospital rank, which ranges between 0 (most efficient) to 1 (least efficient).

There are two striking features about this figure:

- First, hospitals are polarised in their scope: they either treat a small number of conditions (three or fewer, so are located on the lower part of the graph) or they treat most of the ten conditions we have analysed (upper region of the graph). There are no hospitals between these extremes.
- Second, the hospitals at either extreme of the efficiency distribution – those furthest to the left or furthest to the right – are invariably hospitals that treat a small number of conditions. However, amongst those that treat few conditions, efficiency ranking varies across the whole range; this is also true of the hospitals that treat a high number of conditions.

Conclusions

In this work, we set ourselves three study questions:

1. To what extent is resource use driven by the characteristics of patients and of the type and quality of care they receive?
2. After taking these characteristics into account, to what extent is resource use related to the hospital in which treatment takes place?
3. Are conclusions robust to whether resource use is described by costs or by LoS?

The patient-level analyses explained between 32% (stroke) and 72% (breast cancer and knee replacement) of the variation in cost. When LoS was the dependent variable, the corresponding figures were 28% (stroke) and 63% (hip replacement). Looking across the ten treatment types, a number of patterns emerge. Older age is generally associated with higher levels of resource use. Being female is also associated with higher costs and longer stays, although this was not always statistically significant. Where deprivation affected resource use, it more frequently drove up LoS rather than cost.

A higher total number of recorded diagnoses was always associated with higher costs and longer stays; the total number of recorded procedures had a similar impact on stay, but did not always increase cost. If patients experienced adverse events, the main impact on resource use was a lengthened stay in hospital.

For every condition considered, after accounting for a broad range of patient characteristics, we find that there are hospitals where the average cost of treatment is significantly higher than the national average. The challenge for these hospitals is to secure reductions in costs if they are to manage financially under Payment by Results, where a fixed price applies to each treatment.

For some of these high costs hospitals, the average LoS of their patients is also significantly higher than the national average. In such cases, these hospitals might secure reductions in costs by reducing LoS. But a focus on LoS will not always solve the problem: the relationship between average hospital costs and LoS is usually quite weak, with the highest correlation amounting to r=0.41. Even at patient level, the correlation never amounts to more than r=0.50. As a consequence, hospitals identified as having high costs are not always those with excessive LoS.

We explored a range of hospital characteristics that might explain variation in both average cost and LoS, including measures of specialisation and of the volume of activity undertaken. But, with a couple of exceptions, none of these characteristics proved significant explanators.

Instead the answers are likely to be specific to each hospital and two areas might merit further attention. First, high costs may be due to how either indirect or overhead costs have been allocated to the particular patients in question. If so, the problem might be easily solved by correcting the costing process, which entails re-allocating shared costs from these patients to others. While mis-allocation of shared costs may be a problem in some hospitals, it doesn't seem to be widespread, as evidenced by the positive correlation in average costs for treatments where resources might be shared, namely cholecystectomy and hernia (r=0.72) and hip and knee replacement (r=0.54). If costs were mis-allocated between these conditions, the correlations would be negative.

Second, there may be problems with how care is organised in these high cost hospitals. It may be that the only way to uncover the nature of these problems is by visiting the department in question. Our analytical approach allows us to pinpoint the hospitals and the specific areas of operation where more detailed scrutiny is required. Managers should visit those departments with high costs to find out why, knowing that it is not due to the particular characteristics of patients themselves. Failure to identify and address high cost drivers will place the hospital at financial risk under Payment by Results.

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