Variations in provider costs in the hip fracture care pathway*

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Abstract

Objectives:
We analyse the variation in costs for hospitals across the patient care pathway for hip fracture, from emergency admission, to hospital stay and follow-up outpatient appointments.

Methods and data:
We use patient-level data for 2009/10 from the Hospital Episodes Statistics, Reference Cost data and the National Hip Fracture Database. We analyse around 60,000 hip fracture cases in 152 hospitals using a random effects generalized linear multi-level model where the dependent variable is given by the cost incurred in treating a patient through her care pathway.

We control for standard patient socio-economic characteristics, type of intervention, co-morbidities, and discharge destination of patients; for a number of quality indicators, such as whether surgery occurred within 48 hours of admission, whether the patient suffered a pressure ulcers or was readmitted. We also control for source of referral from A&E and type of A&E department and for various characteristics of the hospital itself.

We obtain provider-specific Empirical Bayes estimates of the random coefficients, which we interpret as capturing relative cost-efficiency among hospitals.

Results:
Preliminary results show that both older age and being from a poorer area are positively related to costs. No other demographic variables play an important role. Patients admitted via an emergency service or a 24h Emergency department are also more costly. As expected, having a comorbidity significantly adds to costs, and that patients discharged to their own homes are usually less costly. We find that having surgery on the same day of admission lowers costs, whilst developing pressure ulcers, being transferred between providers, having a CT scan or other radiography or the use of cemented arthroplasty increase cost of care.

Accounting for a greater part of the patient care pathway than is usually feasible, we gain insight into why costs vary among patients and hospitals. We assess the extent to which different ways of organising the care pathway influences costs and quality and identify hospitals with significantly higher costs that risk financial losses under prospective funding.

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Introduction

Proximal femoral fracture (PFF) or hip fracture is one of the commonest reasons for admission to an orthopaedic trauma ward. It is usually caused by a fall affecting an older person with osteoporosis or osteopaenia.

In the UK around 77,000 PFFs occur each year (Marsh et al. 2007); about 85% of those in England. Projections of the prevalence of hip fracture are based on predictions about population growth, changes in the age structure of the population, and changes in the incidence of PPF by age group. Building on methods used by (Holt et al. 2009) to project the hip fracture burden in Scotland, White and Griffiths (2011) estimated changes in the number of PFFs, consequent bed day requirements and financial implications in England. They predicted a significant change in age distribution of hip fracture patients with the mean age increasing from 81 years in 2008 to 86 years in 2033. Over the same period, the population in England is expected to rise from 51.5 million to 62.6 million (21.7%) and the percentage of the population over 60 years of age from 22% to 27.6%. Recent studies have documented a decline in the incidence of PFF among the elderly in Scotland (Holt et al. 2009), Canada (Leslie, O'Donnell, and Jean 2009) and the United States (Brauer et al. 2009; Gehlbach, Avrunin, and Puleo 2007) over the last decade or so. Similarly, White and Griffiths reported a 2.98% decline in the incidence of PFF/100,000 population in England from 2002 to 2008. They calculated that even if the age/gender specific incidence of PFF continues declining (at the same rate), the number of fractures is expected to increase over the next 25 years as the population ages, resulting in significant costs for the NHS. According to their projection the number of PFFs in England will reach 100,000 annually by 2033. Assuming a mean length of stay of 20 days this number translates to an additional 500,000 bed days in 2033 compared to 2008. This is a conservative estimate in comparison to the 1.6 million additional bed days predicted by Hollingworth, Todd, and Parker (1995) assuming that the age/sex specific incidence of PFF remains constant at the 1991-92 level.

The above projections warn of further increases in the already high medical and social care costs for hip fracture patients, currently estimated at about £2 billion annually in UK (NICE 2011). Although PFF may occur at any age in people with osteoporosis or osteopaenia, it predominantly affects elderly patients with the average age of a person presenting with a PFF in the UK of around 83-84 years (NHFD 2011). Residents of care and nursing homes account for about 30% of all patients admitted to hospital with a PFF. These patients are usually more frail, more dependent for daily functioning activities and are more likely to have cognitive impairments compared to other patients. The important implication for future resource use is that an ageing population is likely to place additional burden on hospital and community medical services.

Hip fractures have a major impact on health-related quality of life and, for many patients, bring loss of mobility and independence. Patients experiencing PFF after low-impact trauma are at increased risk of premature death (Abrahamsen et al. 2009; Panula et al. 2011; Richmond et al. 2003) and higher death rates: about 10% die within a month and about one-third die within the year (Brauer et al. 2009; NICE 2011; Nikkel et al. 2012). Most of these deaths are not, however, due to the hip fracture itself, but to the associated conditions and comorbidities that predominantly affect elderly patients.

Clinical evidence-based guidelines have been developed for hip fracture (NICE 2011) which propose protocols around a timely and co-ordinated multi-disciplinary collaborative care approach to improve outcomes for patients with PFF. This encourages orthopaedic surgeons, anaesthetists, ortho-geriatricians and their teams to work more closely together. Because the occurrence of fall and fracture often signals underlying ill health, a comprehensive multidisciplinary approach is required from presentation to subsequent follow-up, including the transition from hospital to community care.

In order to support and encourage the implementation of the clinical guidelines, financial incentives have been developed in the form of top-up payments as part of the prospective payment system Payment by Results (PbR) which funds acute providers in England. A Best Practice Tariff (BPT) for hip fracture care has been established given the clinical consensus around best practice treatment.

Compliance for the BPT is monitored through the National Hip Fracture Database (NHFD) (www.nhfd.co.uk) which was launched in 2007 to provide examples of good practice. All eligible hospitals are registered with the NHFD. While participation is voluntary, around 98% participate by regularly uploading case records and receiving benchmarked feedback that enables clinicians and managers to monitor the care they provide and the outcomes they achieve.

The NHFD provides examples of integrated patient care pathways for hip fracture. These are structured multidisciplinary care plans which detail essential steps in the care of patients and have been proposed as a way of translating the national guidelines into local protocols (Campbell et al. 1998). The degree to which integrated care pathways for PFF succeed in realising the potential for improving patient care is still uncertain (Parker 2004; Smith et al. 2008). Some 'before and after' studies have been unable to demonstrate any benefit in patient outcomes after the introduction of integrated care pathways (Choong et al. 2000; March, Cameron, and Cumming 2000; Roberts et al. 2004). Nevertheless, there are reports of a number of benefits associated with the use of care pathways in clinical practice, including reductions in length of stay in hospital, reductions in costs of patient care, and improved patient outcomes (Beaupre et al. 2006; Currie, Hutchison, and Boyd 2002).

Despite the financial burden of PFF, research on the factors that affect costs following hip fracture is scarce. Two recent US studies emphasized the role of co-morbidities (Nikkel et al. 2012) and medical and nursing interventions (Titler et al. 2007) on hospitalization costs. These analyses are restricted to costs incurred during hospitalisation only, and do not allow for influences on costs that might be due to the characteristics of hospitals or to inefficient practice.

The present work aims to fill this gap. We analyse the variation in costs for hospitals across the patient care pathway for hip fracture from emergency admission, to hospital stay and follow-up outpatient appointments. We map costs to each step and explain variation in costs in the care pathway due to: i) socio-demographic characteristics and clinical conditions of the patient, and ii) characteristics of the providers of care. By looking in detail at the care pathway, we are able to identify which factors are most associated with best practice, and inform policy about what configurations are more likely to yield efficiency gains.

Data

In order to construct the patient care pathway for people suffering hip fracture, we use the Hospital Episode Statistics (HES) data warehouse, containing details of all admissions to National Health Service (NHS) hospitals in England for the fiscal year 2009/10. HES comprises three main sources of information: 1) the Admitted Patient Care (APC) dataset, which includes inpatients and day cases; 2) the Outpatient (OP) dataset, which is made up of individual records for all outpatient attendances; 3) the Accident and Emergency (A&E) dataset, which includes individual records for all A&E attendances.

Costs are not reported in HES, but all English hospitals have to report their activity and costs to the Department of Health (DoH), applying a standard top-down costing methodology to produce "reference costs" (RC) for patients allocated to each Healthcare Resource Group (HRG – the English version of diagnosis related group) in each of their departments (DOH 2008b). We map these costs to each patient according to the hospital and department in which they were treated and the HRG to which they were allocated for each of the above mentioned datasets, building on the process set out in Laudicella, Olsen, and Street (2010). Additionally we refine the matching procedure: i) for OP attendances on the consultant code and the purchaser code, i.e. the code for the organisation commissioning the patient's treatment; ii) for APC episodes, by type of admission (day-case, elective, non-elective) and by assigning per diem costs for patients that stay in hospital beyond HRG-specific length of stay trimpoints. We adjust reported costs by the market forces factor (MFF), this being an index of geographical variation in the prices of land, buildings, and labour (DOH 2008a), designed to account for unavoidable differences in factor prices incurred by different hospitals.

Having mapped costs to all patient records, we select our analytical sample. Following NICE guidelines, the population of interest in this study covers patients aged 18 and older presenting to the health service with a primary clinical diagnosis of fragility fracture of the hip. This definition includes patients with the following types of fracture: intracapsular (undisplaced and displaced), aka femoral neck fractures, and extracapsular (trochanteric and subtrochanteric). Detailed clinical conditions are available in the APC module of HES, so that patients were selected based on one of the following ICD-10 (International Classification of Diseases, Tenth Revision) codes: S720 (neck of femur), S721 (perthrocanteric fracture) and S722 (subtrochanteric). For code S729 (fracture of femur, part unspecified), we also retrieved information from the Office of Population Censuses and Surveys (OPCS), version 4.5, in order to identify the population of interest.[1]

In order to construct the care pathway, we link A&E activity and patients selected in the APC module by means of the unique individual identifier and by identifying only those A&E episodes that occurred within 24 hours before admission to hospital. We link to the pathway OP attendances happening after discharge for the following treatment specialties: i) trauma and orthopaedics, ii) rehabilitation, iii) radiology. We end up with 59,067 patients. As shown in Table 1 the care pathway is quite diverse among the reference population: a) most of the patients (83%) are admitted into hospital passing through an A&E department; b) the vast majority are admitted into the same hospital at which they received A&E care, even though some patients are transferred between

[1] For instance, OPCS 4.5 refers to codes from W370 to W399 for total prosthetic replacement of hip joint.

providers before receiving secondary care; c) almost ¾ of the patients do not have a recorded follow-up OP visit after being discharged.

[Table 1 about here]

As shown in Figure 1 there is considerable cost variation, both within and between providers, in the treatment of inpatient activity. Treatment for some patients is very costly, well above £50,000, even though the average cost is in the range £5,000-£20,000. Our empirical analysis is designed to reveal whether such differences are explained by the characteristics of patients that suffer hip fracture or appear due for to the hospital in which they are treated.

[Figure 1 about here]

We consider a number of patient characteristics (Table 2), including age and gender to ethnicity, admission methods, and destination on discharge. We also control for the level of income deprivation in the patient's area of residence. Female patients represent the majority, making up 72% of our sample; average age is 81 years. 91% of patients are white, while 7% have a poorly coded ethnicity field.

While our analytical sample consists of patients admitted as emergencies, we have been able to match only 83% to the A&E database. There are two possible explanations for this apparent inconsistency: 1) we selected A&E episodes happening within 24 hours of admission, so that it might be possible to link more A&E episodes with inpatient activity by simply extending the time frame; 2) the patient might be admitted as an emergency not only through the A&E department but also direct to the ward or from a consultant outpatient clinic.

A&E data include date and time of arrival, essential to establish a link with the APC module of HES, admission, treatment and conclusion of the A&E episode. Most of the patients are admitted to 24-hour service emergency departments with full resuscitation facilities. However, for almost a third of the A&E sample (or a quarter of the whole sample) we are unable to establish in what kind of department the patient is treated. This is probably due to the lower quality of the recorded field compared to the rest of the database (HESonline 2011). With respect to the source of referral, patients tend to come from other emergency services or self refer.

In our analyses we account for variables as proxies for the severity of the fracture and the patient's condition. Fracture of the neck of femur is the commonest type of injury (72%), followed by the perthrocanteric facture (24%). Generally these traumas happen after a fall, which occur in ¾ of the sample. For a limited number of patients we observe secondary injuries not related to the hip. The vast majority experience multiple surgical procedures. 21% of patients are transferred between providers.

We also report indicators that proxy the quality of care. Slightly less than 75% of the patients have surgery the same day or the day after admission; a quarter receive cemented arthroplasties. Less than 3% develop pressure ulcers, and very few people receive epidural anaesthetic. Imaging is performed on only 6% of patients, but this activity may not be properly coded in medical records.

We computed also an 8% emergency readmission rate within 28 days of discharge. This measure is used by the National Centre for Health Outcomes Development (NCHOD) as a clinical indicator. Furthermore, about 2% of the patients are readmitted after 28 days.

[Table 2 about here]

We are also able to identify comorbidities for each patient (table 3) which we code as binary variables (0/1), as described by Elixhauser et al. (1998). Figure 2 shows the prevalence of comorbidities in our cohort of patients. Hypertension is the main comorbidity, affecting more than 40% of patients, followed by chronic pulmonary disease (14%) and diabetes (12%). Almost a quarter of the sample does not appear to have other coexisting medical conditions not directly related to the principal diagnosis.

[Table 3 about here]
[Figure 2 about here]

More than half of patients are discharged to their usual residence, while almost 14% are transferred to another provider. 7% of patients die in hospital. On average, patients have 0.46 subsequent outpatient attendances related to their hip fracture, a large proportion having none.
We included variables at hospital level (Table 4) from either the NHS Information Centre for the year 2009 or from information included at patient level, which has been grossed up to hospital level. Care for hip fracture is generally provided in fairly large hospitals (average 767 beds), half of them having a Foundation Trust status (a marker for high performance providers). Less than a fifth of the hospitals provide teaching activity. On average almost 400 patients are treated in each hospital, even though there is also lots of variability, as this figure varies from 1 to 1,014. We construct three measures of quality designed to capture general hospital quality over and above the patient-level indicators. The imaging index is reports a summary of imaging activity performed in the hospital.

[Table 4 about here]

There is no dataset that records social care provision at individual level. Instead, we account for the supply of social care provision by measuring the amount and type of services and of registered places in different homes in the local area using data reported on the Care Quality Commission website (www.cqc.org.uk/cqcdata). Details are provided in Table 5.

[Table 5 about here]

Methods

The vehicle for our analysis is the generalized multilevel random intercept model. Our data exhibit a two level structure with patients at level 1 and hospitals where patients are admitted at level 2. The random effects represent unobserved heterogeneity and induce dependence between patients nested in hospitals. The two-level generalized linear model for costs, C_{ij}, of patient *i* in hospital *j* is specified as:

$$h^{-1}\{E[C_{ij}|\boldsymbol{X}_{ij}, u_j]\} = \boldsymbol{\beta X}_{ij} + u_j \equiv \eta_{ij} \qquad i = 1, \dots, I; j = 1, \dots, J \quad (1)$$

Where $\mathbf{X}_{ij}$ is a column vector of patient and hospital characteristics, $\boldsymbol{\beta}$ is a conformable parameter vector, u_j are random intercepts or level 2 hospital specific effects, $h^{-1}(.)$ is the link function and η_{ij} is the linear predictor. In other words the conditional expectation of the response, given the covariates and the random effects, is:

$$\mu_{ij} \equiv \{E[C_{ij}|\boldsymbol{X}_{ij}, u_j]\} = h(\boldsymbol{\beta X}_{ij} + u_j) = h(\eta_{ij}) \quad (2)$$

Costs are assumed to be conditionally independent, given the covariates and the random effects, and have conditional distributions from the exponential family. For this family of distributions, the conditional variance is given by:

$$Var(C_{ij}|\mu_{ij}) = \varphi_{ij} V(\mu_{ij}) \quad (3)$$

Where ϕ_{ij} is a dispersion parameter and $V(\mu_{ij})$ is a variance function specifying the relationship between the conditional variance and conditional expectation. The multilevel linear model works by specifying an identity link, $\mu_{ij} = \eta_{ij}$, and a conditional normal distribution for the costs, so that the variance function is equal to 1 and the dispersion parameter is a free parameter θ, to be estimated jointly with the other parameters. Given the skewed nature of costs, our data fit better by specifying a log link instead of the identity. We avoid the log transformation of the dependent variable that in various simulation exercises has been shown to have worse properties compared to OLS and GLM models where the dependent variable is on the raw scale (Daidone and Street 2011; Deb and Burgess 2003; Jones 2010). Further we avoid the pernicious retransformation problem (Duan 1983; Manning 1998).

After estimating the model with maximum likelihood, we recover hospital random effects in post-estimation using Empirical Bayes techniques to assess the relative cost efficiency of providers. This is accomplished by treating all estimated parameters as known and assuming a normal prior with zero mean and variance $\hat{\theta}$ for the random intercept u_j (Scrondal and Rabe-Hesketh 2009). Posterior means are precision-weighted, that is, they are shrunken towards the mean of the prior distribution. The degree of shrinkage is determined by the number of observations per hospital. We consider comparative standard errors, as described by (Scrondal and Rabe-Hesketh 2009), in order to make appropriate inference regarding the realised values of the estimated random effects.

We estimated various specifications of the linear multilevel random effects model. Our primary specification explains the total cost of hip fracture from admission to A&E to inpatient hospital stay to outpatient follow-up visits. For sensitivity analysis, three more specifications, were estimated i) for hospitalization costs alone, ii) for the costs of the complete pathway excluding provider lever variables and iii) for the combined A&E and inpatient costs (i.e. excluding outpatient costs).

Results

Estimates and standard errors of our primary specification are presented in table 6 in the *full pathway* column.

[Table 6 about here]

Age is positively related to higher total costs of hip fracture care. Patients residing in areas with higher income deprivation incur higher total costs for hip fracture treatment. Sex, race, and the age/sex interaction term do not appear to play an important role. This is in agreement with Titler et al. (2007) who used large scale US data to demonstrate that the cost of hip fracture care is more related to medical and nursing interventions rather than patient demographics.

Patients admitted directly into hospital are more costly than those passing through an A&E department. Of the latter, patients self-referred to a hospital or referred by a GP tend to have lower costs compared to patients admitted through an emergency service. Finally, patients admitted to hospital through a consultant led A&E department are less costly than patients admitted through a 24h Emergency department.

Type of fracture is an important explanatory factor of costs with fracture of neck of femur, pertrochanteric, and subtrochanteric fracture all being significant. Patients diagnosed with secondary non-hip injuries, had multiple surgical procedures, or injured by fall are more costly.

A negative quality outcome such as developing pressure ulcers is associated with higher costs while patients that receive surgery on the same date or the day after admission incur less total costs. As expected, transfer between providers and emergency readmission within 28 days from surgery drive costs up. Treatment cost is also higher for patients undergoing cemented arthroplasty. Similarly administering CT scans or other radiography escalates the cost of treatment.

The presence of any type of comorbidity results in higher costs, with the exception of patients suffering hypothyroidism and metastatic cancer and valvular diseases. Of the 28 comorbidities, 15 have a strong impact (statistically significant at 0.1% level) including chronic pulmonary disease and uncomplicated diabetes, the second and third most common comorbidities. Most of these comorbidities are also found to have a strong impact in Nikkel et al. (2012). Hypertension, the most common comorbidity, is significant at 1%.

Costs vary among patients according to their discharge destination. The total costs of patients discharged to a temporary residence, a nursing home, a facility run by the LA or a non-NHS run residential care are higher compared to those discharged to their usual residence. As might be expected, those discharged to other providers or psychiatric/penal hospitals are less costly, presumably because we have not identified the full pathway for these patients. In-hospital death is barely significant. The number of subsequent outpatient attendances has no influence on the cost of the full pathway, but does appear to be associated with lower inpatient costs.

Hospitals serving a larger number of PPF patients are likely to exhibit lower costs, possibly due to economies of scale in this operation. This doesn’t carry through to the hospital as a whole though, with costs being higher in larger hospitals. No other provider characteristics affect costs.

The supply of social care in the local area generally appears not to have a significant influence on health care costs for these patients.

While patient and provider characteristics explain much of the variation in costs, they do not explain it all. A high degree of variation in the average cost per patient across hospitals is captured by the hospital random effects. Empirical Bayes estimates presented graphically in figure 3 demonstrate relative efficiency across hospitals. Compared to the average performing hospital, the top performing hospital has costs nearly £4000 lower and about 10% of the hospitals have lower costs of around £2000 per patient. The hospital with the poorest financial performance spends nearly £6,000 per patient more than the average.

[Figure 3 about here]

The *inpatient* columns present estimates of the specification for hospitalization costs alone. All signs and significances are the same and only small changes in the magnitudes of estimates are observed. Empirical Bayes estimates and therefore ranking of hospitals are also relatively insensitive to the specification. The other two specifications, not presented for brevity, also delivered similar results.

Discussion

This paper has examined the variation in costs for providers of Proximal femoral fracture (PFF) in England using both patient and provider level data. We have modelled costs across the patient care pathway, from emergency admission, to hospital stay, to follow-up outpatient appointments. We have analysed around 60,000 hip fracture cases in 152 hospitals using a random effects generalized linear multi-level model controlling for i) patient's socio-demographic and clinical characteristics, and ii) provider characteristics.

We contribute to the literature in a number of ways. First, we model a fuller patient care pathway than has previously been done. Nikkel et al. (2012) examine hospitalization costs following hip fracture in the United States controlling for patient, hospital and procedure characteristics. They specifically show that comorbidities significantly increase the cost of hospitalizations following hip fracture even while controlling for other factors. They do not however account for all pathway costs such as A&E and outpatient visits. Second, we model the provider effects by obtaining provider-specific Empirical Bayes estimates of the random coefficients, which we interpret as capturing relative cost-efficiency. This allows us to identify specific providers (and their characteristics) that have opportunities to make significant relative cost improvements for PFF.

We consider a number of limitations to the paper and future research.

First, our pathway remains incomplete. We have not yet tracked patients that continue to receive treatment for PFF from other healthcare providers subsequent to their discharge. We hope to be able to do this in future work. Moreover, we are unable to include social care costs directly in any of our models as these are not available at either patient level. Instead we have included measures of the local supply of home and nursing care in our models to capture the impact of differences in social care provision across the country.

Second, there are concerns about the accuracy of reference costs in terms of whether they truly reflect resource use for individual patients. As an alternative proxy measure of resource use, we will also model length of stay to assess the consistency of results. This will give us an alternative view of provider performance in the care pathway.

Third, we plan to examine which providers are performing significantly above or below the Best Practice Tariff (BPT) BPT and the proportion of providers that are affected by this. The BPT which was introduced in April 2010 pays providers an additional £445 per case (in 2010/11) for the achievement of specified standards (surgery within 36 hours; care by a surgeon and geriatrician; care protocol agreed by a geriatrician, surgeon and anaesthetist; pre/peri-operative assessment by a geriatrician; a geriatrician-led multi-disciplinary rehabilitation; and secondary prevention including falls and bone health assessment). An average unit treating 350 hip fractures per year with 90% compliance of the BPT requirements will therefore receive just over £140,000 of additional income (0.9 x 350 x 455) (Wilson, Harding, and Sahota 2010). Analysis of the impact of the BPT will help identify those providers with significantly higher pathway costs that risk financial losses under Payment by Results. We can also examine which patient care pathways are associated with large deviations from BPT and whether or not providers comply with NICE guidelines on hip fracture.

Fourth, in future analyses we hope to make use of the National Hip Fracture Database (NHFD). The NHFD is audited against six standards: prompt admission to orthopaedic care; surgery within 36 hours and within normal working hours; nursing care aimed at minimising pressure ulcer incidence; routine access to ortho-geriatric medical care; assessment and appropriate treatment to promote bone health; and falls assessment. We have been able to re-create several of these variables at patient level from HES data e.g. surgery on the same date or day after admission (for surgery within 36 hours) and development of pressure ulcers. However, there is a considerable amount of missing data in the NHFD and its use in this paper would have resulted in a large drop in the numbers of observations. We therefore chose not to use the NHFD data but hope to overcome these limitations in future work.

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Tables

Table 1. Pathway from A&E to hospital admission and OP attendance

Pathway type	Frequency	%
A&E H_i -> Admitted H_i, no OP	36057	61.04
A&E H_i -> Admitted H_i -> OP	12226	20.70
No A&E, direct admission, no OP	7682	13.01
No A&E, direct admission -> OP	2455	4.16
Multi A&E H_i -> Admitted H_i, no OP	269	0.46
Multi A&E H_i -> Admitted H_i -> OP	137	0.23
A&E H_i -> Admitted H_j, no OP	88	0.15
A&E H_i -> A&E H_j -> Admitted H_j, no OP	80	0.14
A&E H_i -> Admitted H_j -> OP	46	0.08
A&E H_i -> A&E H_j -> Admitted H_j -> OP	25	0.04
A&E H_i -> A&E H_j -> Admitted H_k, no OP	1	0
A&E H_i -> A&E H_j -> Admitted H_k -> OP	1	0
Total	59,067	100

Table 2. Patient characteristics, n=59,067

Variable	Description	mean	sd
<u>Demographic</u>			
agey	Age in years	81.24	11.47
sex	Gender: female	72.24	44.78
imd04i	Index of multiple deprivation: income domain	0.15	0.11
white	Ehnicity: white	91.14	28.42
othrace	Ehnicity: other	1.53	12.28
racenk	Ehnicity: unknown	7.33	26.06
<u>A&E attendance and source of referral</u>			
aeepisod	A&E attendance	82.84	37.71
aerefem	Referral through emergency services	33.28	47.12
aerefsr	Self referral	30.76	46.15
aerefgp	Referral through GP	2.74	16.33
aerefhp	Referral through health care provider	1.8	13.29
aerefot	Referral through other source	14.26	34.96
<u>A&E department type</u>			
aedptful	24 hour/ full resuscitation facilities	55.27	49.72
aedptcl	Consultant-led mono specialty	0.81	8.95
aedptmi	Other type/minor injury activity	1.02	10.04
aedptnk	Department not known	25.74	43.72
<u>Type and severity of fracture</u>			
multfrct	Multiple hip fracture	0.51	7.16
frneck	Fracture of neck of femur	72.21	44.8
frprtroc	Pertrochanteric fracture	23.99	42.7
frsubtr	Subtrochanteric fracture	3.51	18.4
frnk	Fracture of femur, part unspecified	0.81	8.96
secinjur	Secondary non-hip injuries	0.4	6.31
sprocW	Multiple surgical -W- procedures	92.12	26.95
fallinj	Injury due to fall	76.27	36.57
<u>Quality and treatment indicators</u>			
earlsurg	Surgery same date or day after admission	73.5	44.13
cement	Arthroplasties cemented	26.88	44.34
ulcer	Pressure ulcers	2.46	15.5
epidural	Use of epidural anaesthetic	0.45	6.7
ctscan	Patient had computed tomography	5.03	21.86
image	Patient had other type of imaging	0.76	8.69
readm28	28 days emergency readmission	8.18	27.41
readm	Patient readmitted after 28 days	2.35	15.14
transfer	Patient transferred between providers	21.17	40.85
<u>Discharge destination</u>			
uresdest	Usual residence	54.43	49.8
tresdest	Temporary residence	3.28	17.81
oprvdest	Other provider	13.88	34.57
nursdest	Nursinge home, residential and LA care	8.67	28.13
died	Patient died	7.08	25.66
othdest	Other destination	12.66	33.26
opattc	Outpatient attendances after discharge	0.46	1.06

Notes*:* Also included but omitted for brevity are dummy variables for co-morbidities. Means of binary variables are expressed in percentages. *othdest* includes psychiatric/penal hospital, non-NHS run hospital-medium secure unit, and unknown destination. *aerefot* includes police, Local Authority social services, work, educational establishment, dental GP, community dental services, and other unspecified or unknown sources of referral.

Table 3: Comorbidities

Variable	Comorbidity	Variable	Comorbidity
cnghrtfl	Congestive heart failure	pepulcer	Peptic ulcer disease excluding bleeding
cardarr	Cardiac arrhythmias	lymphoma	Lymphoma
valvdis	Valvular diseases	metcanc	Metastatic cancer
pulmcirc	Pulmonary circulation disorders	tumnomet	Solid tumor without metastasis
pervasc	Peripheral vascular disorders	rheumar	Rheumatoid arthritis
hyperten	Hypertension	coagulop	Coagulopathy
paralys	Paralysis	obesity	Obesity
oneurdis	neurological disorders	weighlos	Weight loss
chpuldis	Chronic pulmonary disease	flueldis	Fluid and electrolyte disorders
diabunc	Diabetes, uncomplicated	bldlsanm	Blood loss anemia
diabcomp	Diabetes, complicated	defanem	Deficiency anemia
hypothyr	Hypothyroidism	alcodrug	Alcohol and drug abuse
renfail	Renal failure	psychos	Psychoses
liverdis	Liver disease	depress	Depression

Table 4: Provider level variables

Variable	Description	mean	sd	min	max
nbeds	# beds	767.55	389	54	2196
teach	Teaching hospital	17.11	37.78	0	100
ftstatus	Foundation Trust status	50	50.17	0	100
nhipfrac	# hip fracture patients	392.44	204.3	1	1014
pcement	% with cemented arthroplasties	0.27	0.14	0	1
pulcer	% developing pressure ulcers	0.03	0.03	0	0.2
pearlsur	% early surgery	0.73	0.13	0	1
imagind	Imaging index	7.74	4.78	0	40.83

Notes: Means of binary variables are expressed in percentages; standard deviations (SD) are reported for continuous variables.

Table 5: Social care variables, n=95

Variable	Description	mean	sd	min	max
hmcrag	# registered home care agency services	58.91	25.27	15	118
nrsagy	# registered nursing agency services	8.51	5.75	0	22
nmcrhm	# registered non-medical care home services	0.23	0.49	0	2
nurhm	# registered nursing home services	45.92	22.78	11	127
reshm	# registered residental home services	146.73	84.41	28	399
rpnmcrhm	# registered places in non-medical care homes	2.2	5.85	0	31
rpnurhm	# registered places in nursing homes	2130.95	967.78	521	5266
rpreshm	# registered places in residental homes	2712.38	1548.41	512	6787
rpnmcrhmpri	# registered places in private non-medical care homes	2.01	5.82	0	31
rpnurhmpri	# registered places in private nursing homes	1933.13	889.47	309	4668
rpreshmpri	# registered places in private residental homes	1943.36	1287.35	82	5937

Table 6. Estimates of the linear random effects model

Variable	*Full pathway*		*Inpatient only*	
	Estimate	Std Error	Estimate	Std Error
Demographic				
agey	35.537	(2.17)***	35.355	(2.17)***
sex	466.54	(212.82)*	463.582	(212.70)*
sex*age	-6.157	(2.64)*	-6.128	(2.64)*
imd04i	561.538	(143.83)***	558.905	(143.76)***
white	51.12	(56.86)	52.149	(56.83)
othrace	197.847	(131.76)	198.415	(131.69)
A&E attendance and source of referral				
aeepisod	-136.267	(62.89)*	-136.567	(62.85)*
aerefsr	-150.918	(51.22)**	-146.837	(51.20)**
aerefgp	-434.352	(102.09)***	-430.625	(102.04)***
aerefhp	-554.449	(118.92)***	-549.552	(118.85)***
aerefot	-138.252	(65.45)*	-134.801	(65.41)*
aedptcl	-896.556	(397.10)*	-1066.019	(396.90)*
aedptmi	-195.916	(244.10)	-203.976	(243.97)
aedptnk	94.335	(87.60)	-59.57	(87.55)
Type and severity of fracture				
multfrct	3591.368	(206.22)***	3589.793	(206.11)***
frprtroc	147.637	(37.10)***	147.166	(37.08)***
frsubtr	513.444	(80.45)***	517.448	(80.41)***
frnk	914.512	(162.58)***	916.828	(162.49)***
secinjur	6107.646	(230.17)***	6103.709	(230.04)***
sprocW	4823.742	(63.31)***	4822.296	(63.27)***
fallinj	-2480.977	(42.41)***	-2481.511	(42.39)***
Quality and treatment indicators				
earlsurg	-753.203	(39.51)***	-752.445	(39.48)***
cement	427.771	(36.72)***	427.317	(36.70)***
ulcer	2305.372	(94.23)***	2305.567	(94.18)***
epidural	-291.789	(222.63)	-300.476	(222.51)
ctscan	1218.023	(67.77)***	1217.532	(67.73)***
image	473.698	(167.54)**	468.534	(167.44)**
readm28	275.421	(54.08)***	274.657	(54.05)***
readm	-192.119	(96.42)*	-192.998	(96.36)*
transfer	406.867	(72.52)***	406.235	(72.48)***
Co-morbidities				
cnghrtfl	347.01	(58.71)***	347.53	(58.68)***
cardarr	149.741	(69.30)*	148.621	(69.26)*
valvdis	149.832	(77.24)	148.591	(77.20)
pulmcirc	474.31	(134.72)***	476.716	(134.64)***
pervasc	354.872	(91.82)***	355.646	(91.77)***
hyperten	78.352	(30.16)**	77.222	(30.14)*
paralys	788.615	(118.15)***	786.965	(118.08)***
oneurdis	672.785	(55.93)***	671.172	(55.89)***
chpuldis	250.293	(41.27)***	250.378	(41.25)***
diabunc	275.298	(44.89)***	273.526	(44.86)***
diabcomp	1536.904	(183.75)***	1536.097	(183.64)***
hypothyr	75.372	(53.81)	74.719	(53.78)
renfail	797.207	(59.99)***	795.542	(59.95)***
liverdis	364.521	(156.24)*	361.685	(156.16)*

pepulcer	1894.561	(251.12) ***	1896.819	(250.98) ***
lymphoma	514.031	(221.39) *	518.397	(221.27) *
metcanc	-57.266	(139.89)	-57.19	(139.82)
tumnomet	206.489	(86.68) *	206.239	(86.63) *
rheumar	169.406	(79.17) *	169.649	(79.13) *
coagulop	691.875	(224.82) **	691.781	(224.70) **
obesity	597.776	(208.50) **	603.944	(208.38) **
weighlos	498.854	(207.25) *	497.522	(207.14) *
flueldis	1086.537	(61.48) ***	1086.383	(61.44) ***
bldlsanm	883.282	(422.90) *	872.972	(422.66) *
defanem	403.179	(92.86) ***	403.418	(92.80) ***
alcodrug	372.992	(91.84) ***	373.474	(91.79) ***
psychos	717.319	(175.32) ***	714.586	(175.22) ***
depress	474.649	(81.90) ***	472.915	(81.86) ***
Discharge destination				
tresdest	404.206	(83.56) ***	404.433	(83.51) ***
oprvdest	-494.367	(79.84) ***	-494.06	(79.79) ***
nursdest	1203.483	(54.93) ***	1201.865	(54.90) ***
died	121.09	(61.99)	120.41	(61.95)
othdest	-490.611	(49.17) ***	120.41	(49.14) ***
opattc	28.135	(14.79)	-491.797	(14.78) ***
Provider level variables				
teach	-709.224	(487.78)	-72.845	(487.88)
ftstatus	388.873	(275.60)	-715.491	(275.66)
nbeds	1.789	(0.68) **	385.987	(0.68) **
nhipfrac	-3.763	(1.20) **	1.796	(1.20) **
pcement	-1578.098	(1163.49)	-3.778	(1163.68)
pulcer	-2171.655	(5429.01)	-1569.108	(5429.69)
pearlsur	-324.005	(1266.81)	-2174.249	(1266.93)
imagind	-4.614	(36.41)	-302.923	(36.41)
Social care variables				
hmcrag	0.907	(2.23)	-5.493	(2.23)
nrsagy	-2.348	(7.31)	0.848	(7.30)
nmcrhm	-31.15	(89.48)	-2.333	(89.43)
nurhm	6.943	(4.98)	-29.997	(4.98)
reshm	-3.271	(1.30) *	6.846	(1.30) *
rpnmcrhm	28.016	(28.98)	-3.284	(28.96)
rpnurhm	-0.324	(0.24)	27.548	(0.24)
rpreshm	0.369	(0.12) **	-0.321	(0.12) **
rpnmcrhmpri	-26.261	(27.00)	0.37	(26.98)
rpnurhmpri	0.143	(0.20)	-26.134	(0.20)
rpreshmpri	-0.307	(0.10) **	0.142	(0.10) **
Constant	3647.238	(1161.75) **	3661.247	(1161.84) **
Level 2 variance	7.395	(0.06) ***	7.395	(0.06) ***
Level 1 variance	8.16	(0.00) ***	8.159	(0.00) ***

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

Figures

Figure 1: Variation of inpatient costs between providers

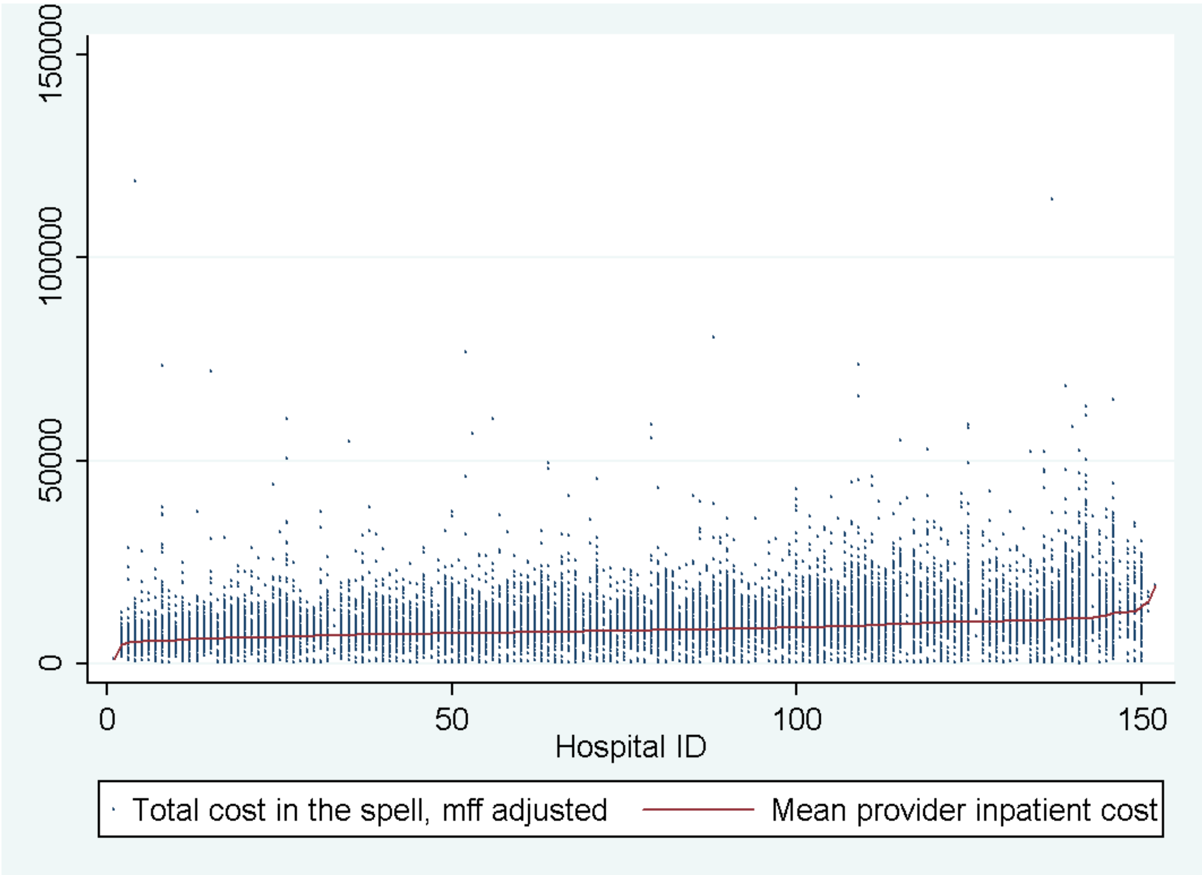

Figure 2: Prevalence of comorbidities in the cohort of patients

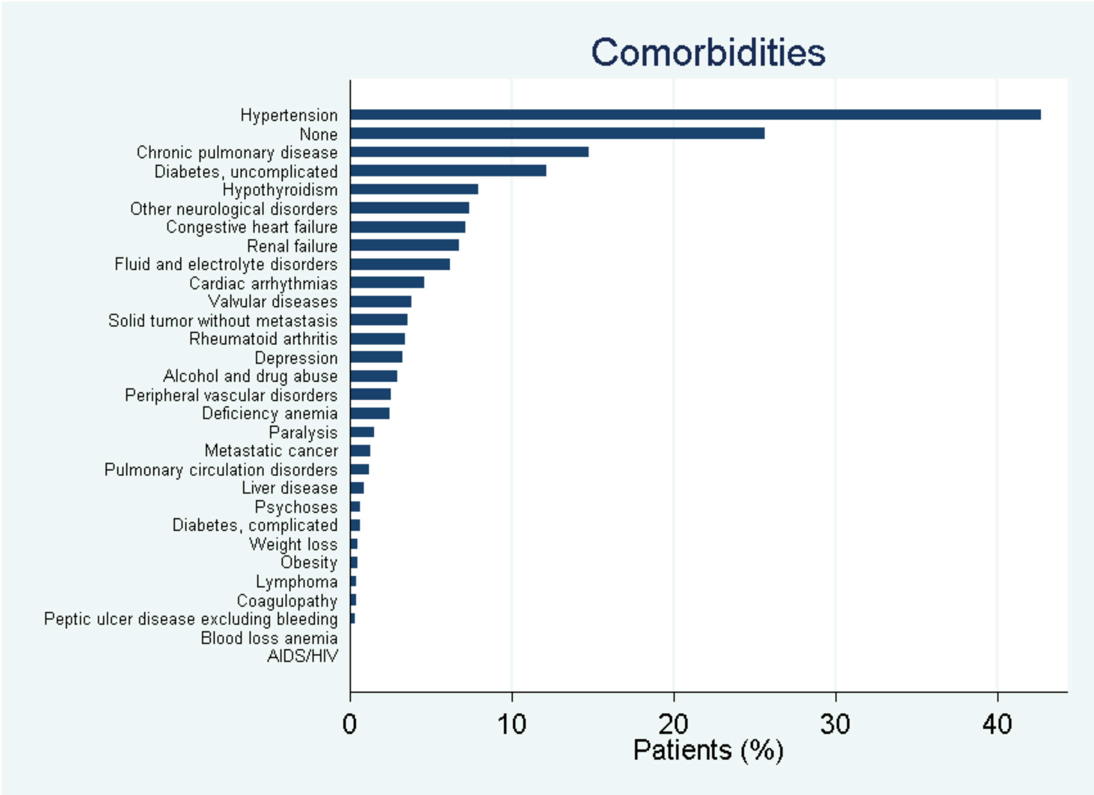

Figure 3: Relative efficiency across hospitals