Association between hospital costs, process quality of care and patient health outcomes in England

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Context: English public hospitals are under increasing pressure to realise cost savings and improve quality of services. However, the relationship between hospital costs, process quality of care and patient health outcomes in England is largely unexplored.

Objective: To determine the association between hospital costs and process quality of care and patient health outcomes in public hospitals in England.

Design: Retrospective cohort study. Raw and risk adjusted pairwise correlations are calculated to examine the association between average costs and process quality indicators at the hospital level. Logistic regression and instrumental variable approach are used to investigate the association between hospital costs and health outcomes at the patient level.

Setting: All NHS public hospitals in England with at least 100 annual admissions of patients with a fractured neck of femur, acute myocardial infarction (AMI) and stroke. For the process quality analysis, hospitals are examined in 2010. For the health outcome analysis, hospitals are followed from 2006 to 2010.

Patients: 217,810 hip fracture (age $\geq$ 65), 219,405 AMI and 250,796 stroke (age $\geq$ 55) emergency admissions. Only patients who experienced no emergency admission in the previous year are included.

Main outcome measurements: Hospital average costs for selected cohort of patients are obtained by merging hospitals Reference Costs returns to patient discharge information in the Hospital Episode Statistics. Patients are followed across different specialists and hospitals until their final discharge. Quality of care is measured using a number of process quality indicators produced by the National Audit of Falls and Bone Health in Older People, the Myocardial Ischemia National Audit Project (MINAP) and the National Sentinel Stroke Clinical Audit. Patient health outcomes are measured using 30 days in-hospital mortality and 28 days emergency readmissions.

Results: Results from the empirical analyses are specific to the cohort of patients considered. In the stroke cohort, we find evidence of a positive and significant correlation between costs and a number of indicators of evidence based best practice in the care provided. Also, we find a negative association between costs and 30-days mortality (0.862 odds; 0.829-0.966, 95% confidence interval) and no association with 28-days readmissions (1.040 odds; 0.959-1.129, 95% CI). In the AMI cohort, we find positive and significant correlations between costs and some indicators of treatment intensity and hospital access to technology. Also, we find a negative correlation between costs and indicators of prompt intervention. No association is found between costs and 30-days mortality (1.005 odds; 0.887-1.138, 95% CI) and 28-days readmissions (1.040 odds ratio; 0.956-1.132, 95% CI). In hip fracture admissions, we find little evidence of a positive association between hospital average costs and process quality indicators and no association between hospital average costs and 30-days mortality (0.997 odds ratio; 0.930-1.068 95% CI) and a small positive association with 365-days readmissions (1.033 odds ratio; 1.000 to 1.066 95% CI).

Conclusion: In England, the relationship between hospital costs, process quality of care and health outcomes is variable across different cohort of patients. In stroke patients, higher costs are associated with better process quality and outcomes of care. In AMI patients, higher costs are positively associated with higher treatment intensity and access to technology and negatively with prompt intervention, but no association is found with health outcomes. In hip fracture patients, higher costs are not associated with either better process quality or health outcomes.

Introduction

In many developed health systems, hospitals are coming under increased pressure to reduce the costs of their services and at the same time improve the quality of care. The call for cost containment has been placed at the centre of the political agenda in European countries with universal access to care funded by the taxpayer. In England, the Department of Health is implementing an ambitious programme of cost savings aimed at securing a £20bn spending reduction by 2015 without compromising frontline services or the quality of care (QUIPP). In particular, the National Health Care (NHS) providers are required to deliver a 4 per cent efficiency savings, and the average price for prospectively reimbursed services fell by 1.5 per cent in 2011[1].

In this context, understanding the relationship between hospital cost and quality of care is essential in order to identify services with the greatest potential for improvements and to avoid unwanted consequences on the quality of care and patient health. Most of the empirical studies so far are based on the US population and health system[2-11] and provide contrasting evidence. A number of studies focusing on short and long term mortality within a single state find that higher spending is associated with better health outcomes[2 8 10]. A common feature of such studies is to use hospital spending at the end of a patient's life to classify hospitals into groups with increasing level of spending and then examining their association with risk adjusted mortality rates from specific admissions. The rationale for such an approach is that end-of-life hospital spending should be correlated with spending for other admissions, but it should not be contaminated by unmeasured health risks amongst the general patient population that cannot be controlled for in the statistical analysis. This approach assumes that hospitals spending more at the end of a patient's life also spend more for other admissions without necessarily attracting patients at higher risk of negative health outcomes than other hospitals.

A similar positive association between spending and outcomes is found in a study examining patient mortality and hospital readmissions after one year from index hospitalisation in the population of US veterans and examining mortality after one year of hospital discharge for AMI admissions[9]. The effect of patient level costs on health outcomes is measured using an instrumental variable (IV) approach that allows for unmeasured patient health risks in a similar fashion to the end-of-life spending approach. The authors use geographical differences in the Medicare Wage Index and general overhead costs across hospitals as instruments to randomise patients with different costs and identify the effect of costs on health outcomes. Their assumption is that these instruments are correlated with patient costs, but uncorrelated with unmeasured health risks.

In contrast a number of studies examining the whole US population find no or negative association between hospital spending and hospital process quality of care and patient health outcomes[5-7 11]. These studies use various methods and units of analysis including regions, hospital admissions and end-of-life spending approach. Their evidence suggests that equal health outcomes are achieved by institutions providing lower intensity of care or the same level of care at lower costs.

Outside the US, there are few empirical studies of the relationship between hospital costs and quality of care[10 12]. One reason is the absence of detailed and reliable data on the costs of hospital services in many countries with free universal access to care. Typically, hospitals operating in such health systems are reimbursed retrospectively with a budget allocated to cover their total costs, or prospectively by a fixed diagnosis-related group (DRG) tariff per service provided. Such payment methods offer little incentive to hospitals to collect detailed information on their service costs. Other reasons are the absence of routine data on the quality of care processes and the lack of general agreement on the appropriate process quality indicators to use. One exception is represented by a recent Canadian study[10] based on the population of the Ontario region. The authors examine a large number of process quality indicators as well as health outcome indicators for patients admitted for an AMI, Congestive Health failure, hip fracture and colon cancer. They use the hospital end-of-life spending approach and find that hospitals in the highest spending tertile have better process quality and health outcomes than hospitals in the lowest tertile.

In England, the association between hospital costs and quality of care is largely unknown. Quality improvements in medical practice might be expensive, but can also save money by reducing the risk of adverse events and in-hospital length of stay. Moreover, improving complex process and organisations of services might generate even greater cost savings. However, there is no evidence as to whether such changes reduce or increase eventual costs in real settings. The existing evidence is limited to studies of simple clinical level changes that are effective in reducing adverse events, such as better antibiotic or antithrombolytic prophylaxis before surgery[13]. However, in such studies it is difficult to include in the analysis all the direct and indirect costs associated with the implementation of the intervention. These elements are often likely to make the difference between a cost saving and a cost increasing intervention in real settings[13 14].

As in other countries, the absence of evidence from England can also be explained by the lack of reliable and detailed data on hospital costs until recent years. From 2003 to 2008, there has been a progressive transformation of the hospital payment system from retrospective to prospective reimbursement based on English DRGs (HRGs). This change has been accompanied by the parallel introduction of a homogeneous costing system for hospital activity apportioning hospital variable costs and overheads to the service units following a top down allocation procedure[15]. As part of this transformation, English hospitals have to report detailed data on their service costs to a centralised system. These returns are used to calculate a fixed HRG tariff to reimburse hospital services[16]. Following the change in the payment system, reasonably reliable data on the cost of hospital services are now available in England and a number of empirical applications have made extensive use of such data in the analysis of hospital efficiency and performance[12 17]. One study[12] examines the variation in hospital costs associated with patient reported outcome measures (PROMS). The authors examine a basket of elective procedures, i.e. hip and knee replacement, varicose vein surgery and groin hernia repair, and assess patient level costs against hospital level average health gains as measured by the EuroQoL-5D and EQ-VAS. They use a cross-section of 2009 hospital administrative data and cost returns and find a negative but not statistically significant association between costs and hospital average health gains.

Evidence on the relationship between hospital costs and quality nevertheless remains limited. There are two aims of the present study. The first is to investigate whether hospitals reporting higher costs provide better process quality of care as measured by indicators of treatment intensity, access to technology, provision of prompt intervention and adherence to medical guidelines on best practice. The second is to investigate whether hospitals reporting higher costs produce better patient health outcomes as measured by 30 days and all in-hospital mortality and 28 and 365 days emergency readmissions. We examine three separate cohorts of patients: stroke, acute myocardial infarction (AMI) and hip fractured admissions.

Methods

Study cohorts

We examine separately three cohorts of patients admitted for acute conditions with high mortality rates and extensively studied in the literature of hospital costs and health outcomes. We include emergency admissions of patients with a primary diagnosis of stroke ICD-10 codes I60-I64 (n= 250,796), AMI ICD-10 codes I21-I22 (n= 219,405), hip fracture ICD-10 codes S72.0-S72.2 (n= 217,810) to NHS hospital trusts (i.e. acute public hospitals) from the financial year 2006 to 2010. The final sample was obtained applying the exclusion criteria described below.

To reduce variation in the health risk of the studied population, we include only patients aged 55 and over for stroke and AMI admissions and age 65 and over for hip fracture admissions. Also, we exclude patients experiencing an emergency admission one year before the index admission.

We create an index spell of care following patients from first admission to final discharge across different specialists and hospital transfers. The patient cohorts are identified by using the diagnosis reported as reason for admitting the patient (primary diagnosis) in the index admission.

To increase stability in the empirical analysis, we include only hospital having at least 100 admissions per year for the cohort of patients under scrutiny. This results in the exclusion of 4 hospitals for stroke, 7 hospitals for AMI and 4 hospitals for the hip fracture cohort. The final sample of hospitals included in the analysis consists of 151 hospitals for stroke, 149 for AMI and 149 for hip fracture cohort.

Finally, we exclude cost outliers by dropping patients below the 0.5 percentile and above the 99.5 percentile of the cost distribution for each cohort. This results in dropping a total of 1% of the population of patients. The exclusion of cost outliers prevents the analysis from being driven by extremely low cost or expensive patients who are likely to be generated by data errors. Similar exclusion thresholds are adopted by the Department of Health to clean hospital cost returns before calculating the payment tariff from the national average[16].

Hospital Costs

Hospital average costs specific to each of the examined cohorts are used as the exposure variable. These are obtained by matching hospital cost returns to patient discharge records and then calculating averages of the costs of all HRG service units provided to patients within cohorts and hospitals.

In England, hospitals cost their activity separately from the actual provision of services at the end of the financial year. Service costs are calculated retrospectively following a top down allocation procedure with total costs decomposed at the level of HRG service units within hospital speciality and type of admission (e.g. elective, non elective, day case, and non elective short stay). In the period covered by our analysis, the HRG4 grouping system classifies hospital activity according to 1,400 different HRG service units. Hospitals allocate total costs to HRG service units following the principle of full absorption costing of the service provided, so that each reported HRG unit cost will include the direct, indirect and overhead costs associated with providing that treatment or care[15]. Detailed costing rules and software to generate final estimates are homogeneous across all hospitals and centrally regulated by the Department of Health. Every year, all NHS hospitals are mandated to submit their HRG cost returns to the Department of Health, which in turn uses this information to calculate a national reimbursement tariff for each of the HRG service units, usually as an average of all hospital HRG cost returns[16]. Therefore, we believe that hospital cost data used in our empirical analysis are consistent and reliable.

We matched HRG service unit costs within hospital speciality and type of admission as reported in the hospital cost returns to their equivalent combination of services reported in the patient discharge records. Cost variation at the level of patient is generated by different care pathways and combination of HRG services provided to patients from admission to final discharge. The total cost of a patient care pathway is attributed to the hospital of first admission. For example, patient A is admitted for an AMI in the cardiology unit of hospital A and receives a primary angioplasty HRG and then is discharged home. In contrast, patient B is first admitted in general medicine in hospital B and receives emergency treatment for a suspected AMI, then she is transferred to the cardiology unit of hospital A and receives a primary angioplasty and also another HRG service from another specialist before being discharged home. The total cost of patient A will be attributed to hospital A and will consist of the cost of a primary angioplasty only; the total cost of patient B will consist of emergency services delivered in hospital B plus primary angioplasty and the other HRG service delivered in hospital A. The total cost of patient B will be then attributed to hospital B.

Finally, hospital average costs are expressed at 2010 average prices in order to remove confounding effects generated by changes in the hospital costing rules and HRG groups over time.

Data sources

Patient records are obtained from the Hospital Episode Statistics (HES) dataset, which collects information on discharge cards of all patients admitted in NHS hospitals (public hospitals).

Hospital costs are obtained from organisation level data presented in the NHS Reference Costs annual returns. The data include the average costs of all hospital services disaggregated at the level of HRG service unit within hospital, speciality and type of admission (elective, day case, emergency, short stay emergency). We collected data on hospital costs from 2006 to 2010 and match these with the patient records reported in the HES dataset.

Hospital level process quality indicators are obtained from three National Clinical Audits conducted in 2010. Specifically, the National Sentinel Clinical Stroke Audit 2010[18] provided the process quality indicators for the stroke cohort.

The process quality indicators for the AMI cohort are obtained from the Myocardial Ischaemia National Audit Project[19] (MINAP).

Process quality indicators for the hip fracture cohort are obtained from the report of the national audit of falls and bone health in older people 2010[20].

Geographical variations in median and mean salary from 2006 to 2010 are obtained from the Annual Survey of Hours and Earnings.

Statistical analysis

The association between hospital costs and process quality of care is examined by calculating pairwise correlation coefficients at the hospital level. We use raw and case-mix adjusted cost indicators and calculate their correlation with each of the process quality indicators described in the "Indicators of quality of care" section.

Raw cost indicators are obtained by dividing hospital average costs by the Market Force Factor (MFF) payment index. Hospital average costs are calculated following the procedure described in the

"Hospital Costs" section. The MFF index adjusts hospital reimbursement payments for differences in unavoidable costs across hospitals, such us geographical differences in the cost of labour and capital[21]. The index ranges from 1.00 to 1.32 meaning that hospitals at the top end receive 32% higher payments for each HRG service provided.

Case-mix adjusted cost indicators allow for the differences in hospital average costs that are due to differences in their patient case-mix. They are calculated as follows: first, patient level costs are regressed against patient characteristics (listed at the end of this section) and hospital fixed effects using linear regression. Second, patient level predicted costs are calculated as a function of patient level characteristics setting hospital fixed effects equal to zero. Finally, the case-mix adjusted indicator is calculated as the ratio of the hospital raw cost indicator to patient level predicted costs averaged within the hospital. The case-mix adjusted indicator equals 1 when raw and case-mix expected hospital average costs are equal and is larger (smaller) than 1 when raw hospital average costs are larger (smaller) than case-mix expected costs. The inclusion of hospital fixed effects in the model ensures that expected costs are based only on observed patient characteristics. It prevents hospital characteristics that might be correlated with the hospital case-mix from being washed out of the case-mix adjustment. For instance, hospitals with access to better technologies, such as primary angioplasty or brain scan, might attract higher proportions of sicker patients. If the characteristics of these patients are entered in the model but the hospital fixed effects are omitted, then the pure influence of patient complexity on average costs may be overstated. A discussion of methods to address this problem can be found elsewhere[22].

In this study we use both a raw and risk adjusted costs indicators. The latter are commonly used in the literature, but sometime criticised as they might increase the bias if hospitals systematically differ in reporting information about their patients[23]. Also, risk adjusted indicators might produce conservative results and reduce the association between cost and quality if some quality process are systematically associated with group of patients whose characteristics are standardised in the risk adjusted indicator[22].

The association between hospital costs and health outcomes is investigated using logistic regression and instrumental variables. We estimate separate models of health outcomes for each cohort using patients as the unit of analysis and hospital average costs as the exposure variable. Hospital average costs mitigate potential endogeneity and censoring issues that arise when using individual level costs, while patient level observations allow us to control for individual risk and to make inference at the individual level.

We adopt an instrumental variable approach to allow for potential bias in the estimation of the effect of hospital costs, which might arise if patients can select (or are selected into) hospitals with different levels of quality according to their health risk. For instance, hospitals with access to higher technology, such as primary angioplasty or brain scan, might attract higher proportions of patients with more severe AMI or Strokes. This might have the effect of raising the costs and worsening the health outcomes for such hospitals if patient health risks are not fully controlled for in the analysis. Typically, randomised control trials avoid this problem by randomly allocating patients across hospitals with different average costs, but such a study design is unfeasible in our study. In contrast, our method of analysis uses an instrumental variable that will act as a randomising device rebalancing the allocation of patients across hospitals. The instrument must hold the following characteristics: it must explain the variation in hospital costs and it must not be correlated with unmeasured determinants of patient health outcomes. We find such characteristics in the area differences in mean and median salary, as used in a previous study[9]. Higher labour costs are likely to result in higher hospital average costs and also to influence management strategies for resource allocation and organisation of services. However, patient risk of negative health outcomes should not be correlated with area differences in salary after controlling for patient and hospital characteristics described below.

We use a two-stage residual inclusion (2SRI) model described elsewhere[24] and already used in healthcare[9]. In the first stage we regress hospital average costs against patient characteristics (as listed below) and the instrumental variables using a Generalised Linear Model with gamma distribution and log-link function. This model is appropriate since the distributions of hospital average costs are skewed to the right in all selected cohorts. In the second stage we regress patient health outcomes against the same patient characteristics included in the first stage model, plus hospital average costs and the regression residual obtained from the first stage model. We use a logistic regression with robust standard errors clustered within hospitals to allow for the correlation of patient health outcomes within hospitals. Statistical analysis was conducted using STATA 11 statistical package.

All models control for the following patients characteristics: 5 years age group (from 55-60 to 95plus), sex, small area income deprivation index grouped in 4 quartiles, weighted Charlson comorbidity index (i.e., the sum of the weighted scores of the Charlson index), total number of secondary diagnosis, dummies for diabetes (ICD-10: E10-E14) chronic ischaemic heart disease (I20, I23-I25), chronic lower respiratory disease (J40-J47), heart failure (I50), renal failure (N17-N19), malignancy (any C code), and dummies for the year of admission (2006-2010). Also, we include controls for cohort specific patient conditions: hemorrhagic (I60, I62), ischemic (I63) or unspecified stroke (I64); ST elevation (I21.4) or non ST elevation in the AMI cohort; fixation (OPCS-4: W19, W20, W24, W25 covering primary open or closed reduction and internal or external fixation), prosthetic replacement of head of femur (W46-W48), any other procedure (including non orthopaedic) and medical management (no procedure performed) in the hip fracture cohort.

Finally, we control for hospitals serving urban or non-urban areas by including an indicator of the proportion of urban areas falling in the hospital catchment area (i.e. 20Km fix radius from the hospital postcode). The Office for National Statistics classifies small geographical areas units (LSOAs) into Urban, Town, and Villages according to their morphology[25]. Hospitals serving higher proportions of non-urban areas might face greater barriers to provide prompt and accessible services, which in turn might influence their outcomes.

Results

Throughout this section hospital average costs are reported at 2010 prices and adjusted for regional price differentials as described earlier in the "Hospital costs" section. Variation in hospital costs is large in each of the examined cohorts. Figure 1 shows the distribution of hospital average costs calculated pooling together 2006-2010 data. The hospital average cost for treating stroke patients is

£2,785 and ranges from £1,389 to £4,724, for AMI patients is £3,034 ranging from £1,706 to £5,233, for hip fracture patients is £7,615 ranging from £1,065 to £5,278. Hospital costs include all the HRG services received by patients in selected cohorts from admission to final discharge as described in the "Hospital cost" section.

Tables 1-4 report the characteristics of hospitals and selected cohorts by quartiles of hospital average costs and interquartile differences. Table 1 shows that the difference in average costs between upper and lower quartiles is £1,489 for stroke, £1,844 for AMI and £2,568 for hip fracture patients. Hospitals in the upper quartile of cost are in larger prevalence teaching hospitals in the stroke (10:1), AMI (12:0) and hip fracture cohort (9:3). Also, they are more likely to have fewer admissions per year in the hip fracture cohort (-88) and to some extent in the AMI cohort (-22), but have slightly higher admissions in the stroke cohort (+26).

Table 2 shows the differences in the patient health risks for each cohort. Patients admitted in the lowest quartile of costs are in general very similar to patients admitted in the upper quartile in each of the examined cohorts. In the stroke cohort, small differences can be found in the weighted Charlson index (+0.048) and total secondary diagnoses (+0.222) suggesting that patients treated in high cost hospitals are to some extent at higher risk of a negative health outcome than patients admitted in low cost hospitals. In the AMI cohort, patients treated in the upper quartile of costs are younger (-1.2 years) and have a smaller weighted Charlson index (-0.062), but are more likely to have chronic ischaemic heart disease (+0.112) and slightly higher number of secondary diagnoses (+0.198). In the hip fracture cohort, patients treated in the top cost quartile have higher Charlson index (+0.061) and more secondary diagnoses (+0.253) again suggesting a slightly higher risk for such patients.

Table 3 shows differences in process quality indicators by cost quartiles in 2010. In the stroke cohort, high cost hospitals are more likely to provide to their patients all 12 or all 9 key indicators of quality of care than least expensive hospitals (+4.7% and +7.7% respectively). Also, they are more likely to provide the 9 key indicators in 2008 (+10.4%). Among the most noticeable differences: patients admitted in high cost hospitals are more likely to spend 90% of their time in a stroke unit (+5.6%), to be initially admitted in a stroke unit (+7.2%) and within 4 hours from call (+5.8%), and to receive a brain scan within 24 hours from stroke (+9.3%). In the AMI cohort, high cost hospitals are more likely be equipped for angioplasty services (+27.5%) and their non-ST elevation patients (nSTEMI) are more likely to be admitted to a cardiac unit (+7.6%) and to receive a coronary angiography (+19%). Both services are recommended by NICE to be provided to ST and non-ST elevation patients and in recent years have been progressively extended to the latter[19]. Among hospitals providing angioplasty services, high cost hospitals are less likely to perform this intervention within 150 min from call (-3.2%) and to admit their patients directly to the intervention centre (-12.2%). In 2010, there are only 68 hospitals providing primary angioplasty services in England and only 62 on routine basis[19]. Hip fracture patens admitted in high cost hospitals are more likely to have their cognitive functions assessed within 72 hours from surgery (+9.9%), attend an exercise programme within 12 weeks from fall (+24%) and have their home assessed for potential hazards (20.8%). However, only a limited number of hospitals reported a sufficient number of eligible cases (≥20) to calculate the last two indicators. Also, a number of quality indicators provide evidence of poorer care in high cost hospitals: their patients are less likely to be mobilise within 24h from surgery (-3.7%), receive appropriate analgesia within 60min of admission (-7.4%), blood pressure reading (-5%) and written information on fall prevention (-6.9%).

Table 4 reports differences in health outcomes by cost quartiles. Stroke patients admitted in high cost hospitals are less likely to die in hospital after 30 days (-2%) or any time (-1.4%), but share a similar probability of being readmitted after 28 days (-0.2%) or 365 days (-0.8%) as compared with patients in low cost hospitals. AMI patients in high cost hospitals have similar probability of dying after 30 (-0.9%) days or any time (-0.9%), but lower probability of being readmitted after 28 days (-1.6%) or 365 days (-3.4%). Hip fracture patients are more likely to die in hospital after 30 days (+1%) or any time (+1.9%) and to be readmitted after 28 days (+1.7%) and 356 days (+3.8%).

Pairwise correlations between cost indicators and process quality indicators are in Table 5-6-7 for stroke, AMI and hip fracture cohorts respectively. We find evidence of a positive and statistically significant association between higher costs and better process quality for stroke patients consistent with descriptive statistics in Table 3. Higher costs are positively correlated with providing 9 key quality processes in 2010 (18.9% correlation with 0.03 p-value) and in 2008 (27.1% with p-value < 0.01) after adjusting for case-mix. Access to brain scan within 24 hours from stroke shows the highest correlation with costs (31.3% with p-value < 0.001). The raw cost indicator provides less conservative predictions showing a greater number of process quality indicators positively correlated with costs. In the AMI cohort, we find evidence of a positive correlation between intensity of treatment and costs for nSTEMI patients receiving a coronary angiography (34.1% with p-value < 0.001), and hospital access to technology and costs for hospital providing primary angioplasty services (20% with p-value 0.02). Also, we find a negative correlation between costs and quality for indicators of prompt intervention: primary angiography within 150 min from calling for help (-29.5% with p-value 0.03) and direct admission to the interventional centre (-32% with p-value 0.01). Similar results are obtained using the raw cost indicator and are consistent with the descriptive statistics in Table 3. In the hip fracture cohort, we find little evidence of an association between process quality and costs. The only quality indicator significantly associated with costs is the assessment of cognitive function within 72h of surgery (23.5% correlation with p-value 0.03); no significant association is found with respect to other process quality indicators.

Table 8 reports odds ratios of patient health outcomes against hospital average costs – measured in £1,000 units. Estimates are obtained using simple logistic regression and two-stage residual inclusion (2SRI) models as described in the “Statistical analysis” section. In the stroke cohort, we find evidence of a positive association between hospital average costs and better patient health outcomes. Odds ratios estimated from simple logistic regression are 0.947 (0.924-0.971, 95% CI) for in-hospital mortality after 30 days and 0.963 (0.939-0.988) for in-hospital mortality any time before patient discharge. In contrast, Odds ratios for 28 days and 365 days emergency readmissions are not statistically different from zero: 0.989 (0.962-1.016) and 0.994 (0.972-1.016) respectively. Odds ratios estimated using 2SIR model show a slightly larger effect of costs consistent with results from the logistic regression: 0.862 (0.810-0.919, 95% CI) and 0.895 (0.829-0.966) for 30 days and any time in-hospital mortality and 1.040 (0.959-1.129) and 0.996 (0.934 to 1.061) for 30 days and 365 days readmissions.

In the AMI cohort, we find no evidence of a significant association between costs and in-hospital mortality both after 30 days and any time before hospital discharge: the odds ratio for the former is 0.995 (0.967-1.023) from logistic and 1.005 (0.887-1.138) from 2SRI model; odds ratio for the latter is 1.001 (0.973-1.031) from logistic and 1.022 (0.905-1.154) from 2SRI model. In contrast, odds ratios from simple logistic regression models show a small and negative association between costs and 28 days and 365 days readmissions: 0.963 (0.942-0.984, 95% CI) and 0.964 (0.943-0.986) respectively. However, results for readmissions are not robust to the 2SRI model suggesting that they might be explained by unmeasured differences in patient health risk.

Similarly, we find no evidence of an association between costs and mortality in the hip fracture cohort, both for 30 days and any time in-hospital mortality: the odd ratio for the former is 1.011 (0.989-1.033) from logistic and 0.997 (0.930-1.068) from 2SRI model; odd ratio for the latter is 1.013 (0.990 to 1.036) from logistic and 0.996 (0.924 to 1.073) from 2SRI model. We find some evidence of a small and positive association between costs and readmissions occurring within 365 days, but no association with readmissions occurring within 28 days: the odd ratio for 28 days readmission is 1.008 (0.993-1.025) from logistic regression and 1.028 (0.980-1.078) from 2SR model; the odd ratio for 365 days readmission is 1.014 (1.001-1.027) from logistic regression and 1.033 (1.000-1.066) from 2SR model. Results of the estimated coefficients from the second stage of the 2SRI models are in Appendix 1-3. Tests of the statistical significance of the instrumental variable used in the 2SRI models are in Appendix 4.

Sensitivity analysis

We test the robustness of our results through a number of checks. We estimate our logistic regression models including the MFF index and regional dummies as covariates to control for differences in regional prices. We include the MFF index as an instrument in the 2SRI models, but find that the predictive power of our original instruments is unchanged. We prefer to use area wages as instrumental variable since it shows higher predictive power than MFF and varies over time (MFF is fixed at 2009).

Discussion

We find evidence that the relationship between costs and quality of hospital care is heterogeneous across different cohorts of patients. We find evidence that higher costs are associated with better quality in the process of care and in the patient health outcomes for stroke care. Patients admitted with a stroke in high cost hospitals are more likely to receive higher standards of care and less likely to die than patients admitted in low cost hospitals. We find evidence that higher costs are associated with access to better technology and supply of more intensive treatment to AMI patients. However, lower costs are associated with providing prompt intervention to these patients. Relative to health outcome, AMI patients admitted to high cost hospitals are not no more likely to die or being readmitted than patients in low cost hospitals. Finally, we find little evidence that higher costs are associated with better process quality of care for patients admitted for a hip fracture and no evidence that higher costs are associated with lower mortality or readmissions for these patients.

In the stroke cohort, we find clear evidence on the mechanism that might lead from higher costs to better health outcomes. High costs are associated with the supply of evidence based best standards of care, such as a brain scan within 24h from stroke, initial admission to a stroke unit, spending 90% of in hospital stay in the stroke unit, supply of aspirin or clopidogrel by 48 hours after stroke. Providing prompt and specialised intervention is central to improving health outcomes of stroke patients. An imaging of the brain within 4.5 hours from symptoms is required to identify the patients eligible for clot busting drug treatment (thrombolysis), which can dramatically improve patient health outcomes. Our study suggests that the provision of prompt and specialised services results in higher costs for the hospitals. Also, higher costs in stroke care are justifiable by better health outcomes. Therefore, cost saving policies in stroke services run a high risk of compromising the quality of care.

In the AMI cohort, evidence on the cost-outcome mechanism is mixed. We find higher costs in hospitals that are able to provide primary angioplasty services and hospitals providing primary angiography to nSTEMI patients. Both processes are recommended by NICE and MINAP since they are known to be associated with better health outcomes. Also, we find evidence that hospitals providing access to primary angioplasty within 150 minutes from call or giving direct access to the interventional centre have lower costs than other hospitals. Early intervention is known to dramatically improve health outcomes in AMI patients and might also be an indicator of hospital efficiency in the organisation of services. Therefore, early intervention might be indirectly associated with lower costs of care for AMI patients. Moreover, in recent years English hospitals have been organised into cardiac networks to coordinate the provision of hospital care, ambulance services, primary and tertiary care to the local population. The main objective of the network is to improve the way services are planned and delivered promoting the diffusion of homogenous standards in the quality of care[19]. This might have contributed to reducing inequalities in the standards of care delivered to AMI patients without having a noticeable impact on their costs. Our analysis show that the net effect of higher costs on patient health outcomes is close to zero. Results from both process quality and health outcomes analyses might be interpreted as evidence that certain efficiency savings can be realised in the organisation of services to AMI patients without compromising on quality.

In the Hip cohort, we find evidence of a substantial variation in hospital costs but no association between costs and process quality or costs and health outcomes. A series of national audits on the status of service of falls and bone health in older people has raised concerns about the standard of care delivered to hip fracture patients[20]. Several aspects of the organisation and provision of services were audited against NICE guidelines for best practice and low rates of compliance were generally found across providers. We also find little evidence of differences in patient case-mix between high and low cost hospitals. Considering this evidence together, we conclude that there may be room for improving both efficiency and quality in the care delivered to hip fracture patients.

The heterogeneity of our findings highlights the importance of using cohort specific indicators of hospital costs for this type of analysis. In England, secondary care services are supplied by a relative small number of large multiservice providers and organised over multiple sites to cover a large local population. In 2010, NHS hospital trusts supplying acute services are 156 with about 126,000 average admissions. Therefore, using a general indicator of hospital costs might result in confounding the cost-quality relationship. In contrast, many US and Canadian studies examine more general measures of hospital spending, such as spending at end of life of the patient. In the North American health systems, secondary care is provided by a large number of relatively smaller hospitals often offering specialised services, hence using more general indicators of hospital spending can be appropriate.

Strengths of the study include the population-based longitudinal design, the examination of indicators of quality in the process of care and the use of an instrumental variable approach. The study also has several limitations. The observational study design limits the extent to which we can identify the components of care responsible for worse or better health outcomes. The use of administrative data gives rise to the possibility of systematic coding and measurement errors. Data on hospital costs are indirectly attribute to hospital services following a top down allocation procedure, rather than collected at the level of individual patients. This might result in measurement errors if hospitals fail to apportion their overheads correctly.

Reducing hospital costs whilst maintaining or improving quality is at the centre of the health policy agenda in England. The Department of Health is implementing an ambitious program of cost savings across all NHS hospitals, as part of the QUIPP project. Hospitals have the difficult task of identifying inefficiencies and waste within their departments and services according to case studies examples (reference). Our study produces the first evidence on the relationship between hospital costs and quality at the national level. By providing such evidence, we hope to help service providers and policy makers to coordinate their efforts more effectively in pursuit of their objective of cost containment and quality improvement.

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Table 1. Hospital characterisitcs by quartiles of average costs (2006-2010)

Stroke	Lower quartile	2	3	Upper quartile	Interquartile differer (Upper-Lower)
hospitals average cost adjusted for regional price differentials (£1	2.045	2.529	2.937	3.534	1.489
average admissions	327	348	409	353	26
teaching hospitals (by year)	1	4	8	11	10
total hospitals by cost quartiles (by year*)	38	35	37	41	
AMI	Lower quartile	2	3	Upper quartile	
hospital average admission cost adjusted for regional price differ	2.139	2.728	3.205	3.984	1.844
hospital average admissions	321	320	357	299	-22
teaching hospitals (by year)	0	4	7	12	12
total hospitals by cost quartiles (by year*)	36	38	36	39	
Hip fracture					
hospital average admission cost adjusted for regional price differ	6.326	7.235	7.841	8.895	2.568
hospital average admissions	360	299	323	274	-86
teaching hospitals (by year)	3	3	9	9	6
total hospitals by cost quartiles (by year*)	37	35	39	38	

Notes:
(*) Quartiles of hospital costs are calculated over the pooled sample of hospital units 2006-2010. Small differences in the number of hospitals in each quartile are due to 3 hospital mergers occurring over the period considered.

Table 2. Patients characterisitcs by quartiles of average costs (2006-2010)

Stroke	Lower quartile	2	3	Upper quartile	Interquartile differer (Upper-Lower)
age	77.7	77.4	77.4	77.2	-0.4
female	0.529	0.527	0.528	0.526	-0.003
Weighted Charlson Index	1.724	1.743	1.773	1.772	0.048
secondary diagnoses in the first episode of care	4.732	4.764	5.054	4.953	0.221
diabetes (E10-E14)	0.165	0.165	0.159	0.161	-0.003
chronic ischaemic heart disease (I20, I23-I25)	0.172	0.178	0.175	0.171	-0.001
chronic lower respiratory disease (J40-J47)	0.091	0.096	0.093	0.089	-0.002
heart failure (I50)	0.048	0.047	0.048	0.042	-0.005
renal failure (N17-N19)	0.031	0.029	0.033	0.030	-0.001
malignancy (any C code)	0.039	0.041	0.044	0.041	0.002
income deprivation index	0.154	0.148	0.156	0.156	0.002
hemorrhagic stroke	0.069	0.076	0.083	0.091	0.022
ischemic stroke	0.584	0.573	0.575	0.616	0.031
unspecified	0.236	0.237	0.226	0.177	-0.059
total patients admitted	58,462	60,539	70,182	61,613	
AMI	Lower quartile	2	3	Upper quartile	
age	74.9	74.4	74.4	73.6	-1.2
female	0.397	0.399	0.394	0.381	-0.016
Weighted Charlson Index	1.939	1.927	1.921	1.877	-0.062
secondary diagnoses in the first episode of care	5.084	5.186	5.132	5.282	0.198
diabetes (E10-E14)	0.203	0.202	0.203	0.194	-0.009
chronic ischaemic heart disease (I20, I23-I25)	0.399	0.410	0.428	0.512	0.112
chronic lower respiratory disease (J40-J47)	0.133	0.136	0.131	0.122	-0.011
heart failure (I50)	0.185	0.169	0.171	0.173	-0.012
renal failure (N17-N19)	0.061	0.062	0.064	0.059	-0.002
malignancy (any C code)	0.037	0.034	0.036	0.030	-0.006
income deprivation index	0.142	0.155	0.161	0.163	0.021
non ST-elevation MI	0.110	0.103	0.109	0.103	-0.006
total patients admitted	54,406	54,305	60,893	49,801	
Hip fracture					
age	83.6	83.5	83.0	83.2	-0.4
female	0.762	0.764	0.767	0.766	0.004
Weighted Charlson Index	0.831	0.861	0.898	0.892	0.061
secondary diagnoses in the first episode of care	5.747	5.778	5.977	5.999	0.253
diabetes (E10-E14)	0.112	0.112	0.118	0.117	0.005
chronic ischaemic heart disease (I20, I23-I25)	0.137	0.140	0.158	0.155	0.017
chronic lower respiratory disease (J40-J47)	0.118	0.124	0.132	0.136	0.018
heart failure (I50)	0.055	0.058	0.060	0.059	0.005
renal failure (N17-N19)	0.041	0.045	0.048	0.046	0.005
malignancy (any C code)	0.038	0.040	0.040	0.041	0.004
income deprivation index	0.129	0.129	0.165	0.170	0.041
fixation (W19, W20, W24, W25)	0.412	0.423	0.422	0.421	0.008
prosthetic replacement of head of femur (W46-W48)	0.376	0.397	0.377	0.354	-0.022
any other procedure	0.063	0.056	0.063	0.064	0.001
no procedure	0.149	0.124	0.137	0.162	0.013
total patients admitted	62,913	51,329	57,405	46,163	

Table 3. Process quality indicators by quartiles of average costs; % of compliance over elegible cases (2010)

Stroke	Lower quartile	2	3	Upper quartile	Interquartile differer (Upper-Lower)
1. Spending at least 90% of stay on a stroke unit	59.6	58.7	63.2	65.2	5.6
2. Screening for swallowing disorders within 24hrs after admission	85.9	84.2	82.4	84.6	-1.3
3. Brain scan within 24hours of stroke	65.9	71.9	71.8	75.1	9.3
4. Aspirin or clopidogrel by 48 hours after stroke	90.1	92.2	92.6	94.1	4.1
5. Physiotherapy assessment within 72hrs of admission	91.3	92.2	90.0	92.1	0.8
6. Assessment by Occupational Therapist within 4 working days of admissior	86.7	82.1	84.6	82.1	-4.6
7. Weighed at least once during admission	86.2	80.1	83.7	89.0	2.8
8. Mood assessed by discharge	82.5	80.8	77.1	82.1	-0.4
9. Rehabilitation goals agreed by multi-disciplinary team by discharge	94.4	96.9	92.4	92.4	-1.9
10. Swallow assessment within 72hours	86.5	86.6	83.3	85.3	-1.1
11. Initially admitted to a stroke unit	36.9	32.7	38.0	44.1	7.2
12. Rehab goals agreed by the multi-disciplinary team within 5 days of adm.	79.0	80.6	74.9	78.1	-0.8
13. Diagnosis discussed with patient	77.3	82.6	78.8	78.3	1.1
14. Admitted to stroke unit within 4 hours	40.2	36.2	40.1	46.0	5.8
15. Initially admitted to a general assessment unit	58.1	62.0	55.0	50.5	-7.6
16. Receiving all key 12 indicators in 2010 (1-13 excl. 9)	18.1	15.4	12.3	22.8	4.7
17. Receiving all key 9 indicators in 2010 (1-9)	29.8	31.4	32.3	37.6	7.7
18. Receiving all key 9 indicators in 2008 (1-9)	12.7	11.1	17.5	23.1	10.4
hospitals submitting >=20 eligible cases	36	34	34	36	

AMI	Lower quartile	2	3	Upper quartile	
1. Hospital providing primary angioplasty	34.2	52.7	61.6	61.7	27.5
hospitals submitting >=20 eligible cases	69	69	66	68	
2. Primary angioplasty within 90 mins of arrival at interventional centre	88.8	84.9	86.5	89.1	0.3
hospitals submitting >=20 eligible cases	12	26	28	33	
3. Primary angioplasy within 150 mins of calling for help	85.5	85.0	82.6	84.2	-1.3
hospitals submitting >=20 eligible cases	15	26	32	35	
4. Primary angioplasy 150m of calling w direct adm to intervent centre	90.4	83.3	84.7	87.2	-3.2
hospitals submitting >=20 eligible cases	12	24	28	33	
5. Patients with direct admission to Interventional Centre	91.8	86.8	81.0	79.6	-12.2
hospitals submitting >=20 eligible cases	19	30	38	37	
6. nSTEMI patients admitted to cardiac unit or ward	49.8	53.7	57.1	57.4	7.6
hospitals submitting >=20 eligible cases	65	65	64	63	
7. nSTEMI patients seen by a cardiologist or member of team	90.0	91.7	93.6	89.5	-0.5
hospitals submitting >=20 eligible cases	69	67	66	66	
8. nSTEMI patients referred for or having coronary angiography	47.4	59.8	67.9	66.4	19.0
hospitals submitting >=20 eligible cases	67	67	66	65	
Secondary prevention medications					
9. Aspirin	98.3	98.4	98.5	98.5	0.2
hospitals submitting >=20 eligible cases	67	65	66	68	
10. Beta blocker	94.1	94.9	95.8	96.2	2.1
hospitals submitting >=20 eligible cases	67	63	66	66	
11. Satins	95.9	96.7	96.9	96.4	0.5
hospitals submitting >=20 eligible cases	67	65	66	68	
12. ACE inhibitor	92.2	93.8	94.0	93.5	1.3
hospitals submitting >=20 eligible cases	69	65	66	66	
13. Clopidogrel/Thienopyridine inhibitor	93.7	93.3	95.3	95.2	1.6
hospitals submitting >=20 eligible cases	69	63	66	68	

Hip fracture					
1. Adequate analgesia within 60 min of admission	69.6	69.7	64.4	62.2	-7.4
hospitals submitting >=20 eligible cases	24	25	27	26	
2. Assessment of cognitive function within 72h of surgery	23.5	30.6	26.6	33.4	9.9
hospitals submitting >=20 eligible cases	22	17	24	20	
3. Attempt to mobilise the patient within 24h of surgery	75.1	62.9	63.6	71.4	-3.7
hospitals submitting >=20 eligible cases	22	17	24	20	
4. Documented lying and standing blood pressure readings	40.3	44.4	28.3	35.3	-5.0
hospitals submitting >=20 eligible cases	24	25	27	26	
5. Patient attending exercise programme within 12w of fall	37.9	30.5	51.8	61.8	24.0
hospitals submitting >=20 eligible cases	9	8	16	9	
6. Home hazard assessment of the patient's own environment	30.0	4.4	18.0	50.8	20.8
hospitals submitting >=20 eligible cases	4	2	5	5	
7. Anti-resorptive therapy for osteoporosis	60.9	60.2	56.8	64.2	3.2
hospitals submitting >=20 eligible cases	24	25	27	26	
8. Written falls prevention info given to the patient or carer	18.4	16.9	13.7	11.5	-6.9
hospitals submitting >=20 eligible cases	24	25	27	26	
9. Median time waited before operation	1.1	1.0	1.1	1.0	-0.1
hospitals submitting >=20 eligible cases	36	35	36	35	

Table 4. Health outcomes by quartiles of hospital average costs (2006-2010)

Stroke	Lower quartile	2	3	Upper quartile		Interquartile differer (Upper-Lower)
30 days in-hospital mortality	0.215	0.211	0.199	0.195		-0.020
patient dead at discharge	0.254	0.251	0.240	0.240		-0.014
28 days emergency readmission	0.114	0.122	0.116	0.116		0.002
365 days emergency readmission	0.395	0.404	0.397	0.404		0.008
total patients admitted	58,462	60,539	70,182	61,613		
AMI	Lower quartile	2	3	Upper quartile		
30 days in-hospital mortality	0.114	0.113	0.108	0.105		-0.009
patient dead at discharge	0.122	0.121	0.117	0.113		-0.009
28 days emergency readmission	0.176	0.171	0.166	0.160		-0.016
365 days emergency readmission	0.464	0.454	0.450	0.430		-0.034
total patients admitted	54,406	54,305	60,893	49,801		
Hip fracture						
30 days in-hospital mortality	0.070	0.075	0.077	0.080		0.010
patient dead at discharge	0.101	0.109	0.109	0.120		0.019
28 days emergency readmission	0.117	0.121	0.130	0.134		0.017
365 days emergency readmission	0.369	0.373	0.396	0.407		0.038
total patients admitted	62,913	51,329	57,405	46,163		

Table 5. Pairwise correlations between hospital average costs and process quaity indicators - Stroke cohort (2010)			
Process quality indicators		row cost indicator	risk adjusted cost
1. Spending at least 90% of stay on a stroke unit	correlation	0.2036*	0.1553
	p-value	0.0158	0.0668
	observarions	140	140
2. Screening for swallowing disorders within 24hrs after admission	correlation	0.0874	0.0163
	p-value	0.3048	0.8488
	observarions	140	140
3. Brain scan within 24hours of stroke	correlation	0.3609*	0.3126*
	p-value	0	0.0002
	observarions	140	140
4. Aspirin or clopidogrel by 48 hours after stroke	correlation	0.2023*	0.1373
	p-value	0.0165	0.1057
	observarions	140	140
5. Physiotherapy assessment within 72hrs of admission	correlation	0.1047	-0.0342
	p-value	0.2181	0.6886
	observarions	140	140
6. Assessment by Occupational Therapist within 4 working days of admi	correlation	0.0168	-0.0782
	p-value	0.844	0.3586
	observarions	140	140
7. Weighed at least once during admission	correlation	0.1775*	0.0872
	p-value	0.0359	0.3057
	observarions	140	140
8. Mood assessed by discharge	correlation	-0.008	-0.0765
	p-value	0.9252	0.3689
	observarions	140	140
9. Rehabilitation goals agreed by multi-disciplinary team by discharge	correlation	-0.0644	-0.1102
	p-value	0.45	0.1948
	observarions	140	140
10. Swallow assessment within 72hours	correlation	0.0296	-0.0378
	p-value	0.7287	0.6571
	observarions	140	140
11. Initially admitted to a stroke unit	correlation	0.1731*	0.1387
	p-value	0.0409	0.1021
	observarions	140	140
12. Rehab goals agreed by the multi-disciplinary team within 5 days of a	correlation	0.075	0.0039
	p-value	0.3783	0.9633
	observarions	140	140
13. Diagnosis discussed with patient	correlation	0.1292	0.0256
	p-value	0.1282	0.7636
	observarions	140	140
14. Admitted to stroke unit within 4 hours	correlation	0.1757*	0.1412
	p-value	0.0379	0.0962
	observarions	140	140
15. Initially admitted to a general assessment unit	correlation	-0.1931*	-0.1474
	p-value	0.0223	0.0822
	observarions	140	140
16. Receiving all key 12 indicators in 2010 (1-13 excl. 9)	correlation	0.1823*	0.1221
	p-value	0.0317	0.1521
	observarions	139	139
17. Receiving all key 9 indicators in 2010 (1-9)	correlation	0.2804*	0.1887*
	p-value	0.0008	0.0255
	observarions	140	140
18. Receiving all key 9 indicators in 2008 (1-9)	correlation	0.2785*	0.2706*
	p-value	0.0013	0.0018
	observarions	130	130
Note:			
Process quality indicators reported in 2010			
Cost indicators ted over 2009-2010			
Only hospital submitting at least 20 elegible cases are included			

Table 6. Pairwise correlations between hospital average costs and process quaity indicators - AMI cohort (2010)			
Process quality indicators		row cost indicator	risk adjusted cost
1. Hospital providing primary angioplasty	correlation	0.1723*	0.2002*
	p-value	0.0418	0.0177
	observarions	140	140
2. Primary angioplasty within 90 mins of arrival at interventional centre	correlation	0.0846	0.1013
	p-value	0.5593	0.4841
	observarions	50	50
3. Primary angioplasy within 150 mins of calling for help	correlation	-0.2755*	-0.2947*
	p-value	0.0417	0.029
	observarions	55	55
4. Primary angioplasy 150m of calling w direct adm to intervent centre	correlation	-0.1041	-0.1254
	p-value	0.4765	0.3905
	observarions	49	49
5. Patients with direct admission to Interventional Centre	correlation	-0.3747*	-0.3210*
	p-value	0.0025	0.0103
	observarions	63	63
6. nSTEMI patients admitted to cardiac unit or ward	correlation	0.1569	0.1053
	p-value	0.0723	0.2295
	observarions	132	132
7. nSTEMI patients seen by a cardiologist or member of team	correlation	-0.1168	-0.1004
	p-value	0.1725	0.2412
	observarions	138	138
8. nSTEMI patients referred for or having coronary angiography	correlation	0.3031*	0.3405*
	p-value	0.0003	0
	observarions	136	136
Secondary prevention medications			
9. Aspirin	correlation	-0.2263*	-0.1578
	p-value	0.0078	0.0655
	observarions	137	137
10. Beta blocker	correlation	-0.1266	-0.0731
	p-value	0.1434	0.3996
	observarions	135	135
11. Satins	correlation	-0.0893	-0.1011
	p-value	0.2993	0.2397
	observarions	137	137
12. ACE inhibitor	correlation	-0.0948	-0.1137
	p-value	0.2705	0.1859
	observarions	137	137
13. Clopidogrel/Thienopyridine inhibitor	correlation	-0.0458	-0.0372
	p-value	0.595	0.6663
	observarions	137	137
Note:			
Process quality indicators reported in 2010			
Cost indicators calculated over 2009-2010			
Only hospital submitting at least 20 elegible cases are included			

Table 7. Pairwise correlations between hospital average costs and process quaity indicators - hip fracture cohort (2010)			
Process quality indicators		row cost indicator	risk adjusted cost indicator
1. Adequate analgesia within 60 min of admission	correlation	-0.1244	-0.0498
	p-value	0.2127	0.6191
	hospitals	102	102
2. Assessment of cognitive function within 72h of surgery	correlation	0.2253*	0.2349*
	p-value	0.0406	0.0326
	hospitals	83	83
3. Attempt to mobilise the patient within 24h of surgery	correlation	0.0486	0.0077
	p-value	0.6624	0.9447
	hospitals	83	83
4. Documented lying and standing blood pressure readings	correlation	-0.0292	-0.0701
	p-value	0.771	0.4835
	hospitals	102	102
5. Patient attending exercise programme within 12w of fall	correlation	0.2214	0.247
	p-value	0.1587	0.1148
	hospitals	42	42
6. Home hazard assessment of the patient's own environment	correlation	0.4266	0.407
	p-value	0.0994	0.1176
	hospitals	16	16
7. Anti-resorptive therapy for osteoporosis	correlation	0.1055	0.0614
	p-value	0.2912	0.5401
	hospitals	102	102
8. Written falls prevention info given to the patient or carer	correlation	-0.0291	-0.0641
	p-value	0.7712	0.5222
	hospitals	102	102
9. Median time waited before operation	correlation	-0.0769	-0.0474
	p-value	0.3628	0.5757
	hospitals	142	142
Note:			
Process quality indicators reported in 2010			
Cost indicators calculated over 2009-2010			
Only hospital submitting at least 20 elegible cases are included			

Table 8. Hospital average costs and patient health outcomes - Results from Logistic and two-stage inclusion residuals models (2006-2010)									
		30 days in-hospital mortality		Patient dead at discharge		28 days emergency readmission		365 days emergency readmission	
Cohort	VARIABLES	Logistic	2SIR	Logistic	2SIR	Logistic	2SIR	Logistic	2SIR
Stroke	cost	0.947	0.862	0.963	0.895	0.989	1.04	0.994	0.996
		(0.924 to 0.971)	(0.810 to 0.919)	(0.939 to 0.988)	(0.829 to 0.966)	(0.962 to 1.016)	(0.959 to 1.129)	(0.972 to 1.016)	(0.934 to 1.061)
	Observations	250796	250796	250796	250796	189121	189121	189121	189121
	# Hospital	151	151	151	151	151	151	151	151
AMI	cost	0.995	1.005	1.001	1.022	0.963	1.040	0.964	0.956
		(0.967 to 1.023)	(0.887 to 1.138)	(0.973 to 1.031)	(0.905 to 1.154)	(0.942 to 0.984)	(0.956 to 1.132)	(0.943 to 0.986)	(0.877 to 1.043)
	Observations	219405	219405	219405	219405	193483	193483	193483	193483
	# Hospital	149	149	149	149	149	149	149	149
Hip	cost	1.011	0.997	1.013	0.996	1.008	1.028	1.014	1.033
		(0.989 to 1.033)	(0.930 to 1.068)	(0.990 to 1.036)	(0.924 to 1.073)	(0.993 to 1.025)	(0.980 to 1.078)	(1.001 to 1.027)	(1.000 to 1.066)
	Observations	217810	217810	217810	217810	194071	194071	194071	194071
	# Hospital	149	149	149	149	149	149	149	149