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# Have hospital readmissions increased in the face of reductions in length of stay? Evidence from England

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ABSTRACT

We assess the relationship between changes in hospital length of stay (LoS) and hospital quality, as measured by 28-day emergency readmission. We estimate regression models to analyse LoS and other factors associated with readmission for all those admitted for hip replacement ($n$ = 496,334), hernia repair ($n$ = 413,712) or following a stroke ($n$ = 480,113) in England between 2002/3 and 2007/8. There were reductions in LoS over time while changes in crude readmission rates varied by condition. Given the high mortality rate for stroke, it is critical to account for the probability of surviving the initial admission when evaluating readmissions. Conditional upon survival, the probability of readmission was greater for stroke patients who originally had a shorter LoS and for hernia patients who had an overnight stay but there is no relationship between LoS and readmission for patients who had hip replacement. The evidence does not generally suggest that reductions in LoS were associated with an increased probability of emergency readmission.



## 1. Introduction

Concerns have been voiced that pressure for hospitals to reduce length of stay (LoS) may have adverse consequences on the quality of care experienced by patients. The "quicker and sicker" argument posits that if patients are discharged prematurely, in a less stable condition, they are at greater risk of subsequent readmission to hospital. Various studies have explored the relationship between LoS and readmission, most famously that by Kosecoff et al. who found some evidence to support the "quicker and sicker" argument following the introduction of prospective payment for Medicare patients in the United States [1]. Evidence from later studies is not definitive: some finding no relationship [2,3], others that reductions in LoS were associated with increased readmissions [4], and another that longer LoS was associated with higher readmission [5].

To guard against adverse consequence of premature discharge, some jurisdictions penalise hospitals with higher than expected readmission rates [6,7]. This requires taking account of the characteristics of patients that might be related to the probability of readmission. Such predictive factors include the patient's functional status, presence of co-morbidities, the type of procedure performed, whether there were post-operative complications [8,9]; measures of socioeconomic status, such as poverty, education level, housing and marital status [10,11]; and organisational characteristics of the local health-system [12]. But in a systematic review of risk prediction models for hospital readmissions, most were found to perform poorly [13], which could be due partly to the limited information in routine administrative datasets.

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Even with better risk-adjustment, readmission rates have been criticised as a performance measure because they are correlated with another commonly used measure of hospital quality, namely in-hospital mortality [14]. If hospitals are more successful at ensuring that patients survive their initial admission, their readmission rates will likely be higher because the average health status of their survivors will be lower than if those most at risk of death had, indeed, died. In view of this, Laudicella et al. argue that readmission rates should be calculated conditional upon the likelihood that patients survive the initial admission [14]. By the same token, the relationship between LoS and readmission should also be estimated conditional upon survival. Previous studies have not done this, thereby potentially providing an inaccurate assessment of the relationship.

We employ this analytical approach, and explore the relationships between LoS, in-hospital mortality and readmissions. We focus on patients admitted to hospitals with one of three conditions, stroke ($n$ = 480,113), hip replacement ($n$ = 496,334) and hernia repair ($n$ = 413,712), chosen because patients with these conditions differ markedly in terms of their LoS, and mortality and readmission rates. We evaluate these relationships for all patients admitted to English hospitals between the fiscal years 2002/3 through to 2007/8. This was a period when hospitals were under ever increasing pressure to reduce LoS, brought about by the phased introduction of the English version of prospective payment known as Payment by Results [15]. Receiving a fixed payment – the national tariff – for each type of patient treated, hospitals had stronger incentives to reduce the average cost of care, the most obvious strategy being to reduce LoS. Indeed, for all three conditions, there were pronounced reductions in LoS (or in the probability of staying overnight) over the period. We use 2002/3 as the first study period because this is the year prior to the introduction of PbR. In our exploration of the relationships between LoS, in-hospital mortality and readmissions we condition on the proportion of hospital income received from PbR, noting that other studies have found an association with LoS but not with mortality or readmission [16].

The remainder of the paper is organised as follows. In Section 2 we detail the methods we employ to explore the relationships between mortality, readmission and LoS. Section 3 provides details of the study dataset and Section 4 contains our empirical results. Section 5 discusses our results and conclusions.

## 2. Methods and modelling approach

We examine the relationship between LoS and emergency re-admission within 28 days after discharge, conditional on patients surviving their initial hospital stay. Rather than study all patients admitted to hospital, we focus on people admitted for stroke care, hip replacement and hernia repair because they have very different baseline LoS and mortality and re-admission rates.

The probability of in-hospital survival is estimated as a probit model. In modelling the probability of readmission we follow Laudicella et al. [14] who recognise that the likelihood of readmission is, in part, a reflection of the survival rate associated with the initial admission. If patient characteristics are not perfectly observable and hospitals differ in the quality of care they provide, then hospitals with low mortality rates are likely to have a larger share of un-observably sicker patients at risk of a readmission.

To address this, Laudicella et al. [14] estimate Heckman's bivariate sample selection model, with the probability of readmission conditioned on survival. This involves identifying variables that explain the probability of survival (the selection equation) but which are uncorrelated with the probability of readmission (the outcome equation). Laudicella et al. note that mortality risk is greater during weekends and over long bank holiday periods (such as at Easter and Christmas) because experienced nursing and medical staff are less available [17]. But the day of the original admission has no bearing on the probability of readmission, this being dependent '. . .on post-operative care that can be provided more flexibly over a long period of time once survival has been assured.' We adopt this identification strategy by including indicators of the admission day in the survival model but not in the readmission model.

The bivariate sample selection model comprises two equations. We first model the probability of patient $i$ in hospital $h$ at time $t$ surviving the first admission, as a function of the latent propensity of surviving $S^*_{iht}$

$$S^*_{iht} = \propto + \beta_1 X_{iht} + \beta_2 D_{iht} + \gamma Z_{ht} + T_t + \varepsilon_{1iht}$$

$$S_{iht} = \begin{cases} 1 & \text{if } S^*_{iht} > 0 \\ 0 & \text{if } S^*_{iht} \le 0 \end{cases}$$

where $X_{iht}$ is a vector of socio-economic, diagnosis and treatment variables measured for each patient; $D_{iht}$ is a vector of dummy variables reflecting the day of admission or whether it occurred during Christmas, Easter or bank (public) holidays; $Z_{ht}$ is a vector of characteristics describing the hospital, including teaching status, location and the proportion of the hospital's funding that was subject to PbR; $T_t$ is a vector of year dummies (baseline 2002/3); and $\varepsilon_{1iht}$ is random error assumed to take a bivariate standard normal distribution and to be uncorrelated with the explanatory variables.

We allow for correlation between $\varepsilon_{1iht}$ and the equivalent error term $\varepsilon_{2iht}$ from the readmission equation, and model readmission conditional upon the patient having survived the original admission, assuming a latent propensity of readmission $R^*_{iht}$ observed only when $S^*_{iht} > 0$:

$$R^*_{iht} = \propto + \beta_1 LoS_{iht} + \beta_2 X_{iht} + \gamma Z_{ht} + T_t + u_{ht} + \varepsilon_{2iht}$$

$$R_{iht} = \begin{cases} 1 & \text{if } R^*_{iht} > 0 \\ 0 & \text{if } R^*_{iht} \le 0 \end{cases}$$

where $\mathrm{LoS}_{iht}$ is vector of variables including the patient's LoS and LoS inter-acted with the year of admission, which captures trends in LoS over time. These models are estimated separately for the three conditions. If there is no evidence of sample selection, or the identification strategy does not hold, the probability of readmission is estimated without having conditioned on survival.

## 3. Data and sources

### 3.1. Patient-level variables

The estimation of the survival and readmission models requires the identification of: (i) those patients that are admitted for each of the selected conditions; (ii) those patients that die during their initial spell in hospital; and (iii) those patients that are subsequently re-admitted as emergencies within 28 days of their initial discharge from hospital (including those that occur in subsequent fiscal years). We follow the methodology employed by the National Centre for Health Outcomes Development (NCHOD) in which cancer, chemotherapy, learning disability, maternity, or psychiatry are not counted as readmissions [18].

We analyse data from the Hospital Episodes Statistics (HES) database. This contains details of all NHS funded patients admitted to public and private hospitals and treatment centres in England. On admission to hospital each patient is assigned to the care of a specific consultant and the records within the database are known as 'consultant episodes'. When a patient leaves the care of a particular consultant, their consultant episode becomes a 'finished consultant episode' (FCE). A multi-episode period of care within the same hospital is known as a spell of care. Each patient's record contains information about the patient, including diagnoses, operative procedures and length of stay.

Stroke patients are defined as those with a primary diagnosis of ICD-10 I61 (intracerebral haemorrhage), ICD-10 I63 (cerebral infarction) or ICD-10 I64 (unspecified stroke). Hip replacement patients are those with an OPCS4 primary operative procedure of W37, W38, W39, W46, W47, W48, W93, W94 or W95. Inguinal hernia patients are those with a primary diagnosis of ICD-10 K40 and primary operative procedure of T20 or T21. We identify all patients aged over 1 year admitted during six 12-month periods (for the six fiscal years from 2002/3 to 2007/8 inclusive).

Length of stay is measured from the day of admission to day of discharge inclusive. We interact LoS with the year of admission to capture underlying trends in LoS over time.

We use HES to account for patient characteristics. Five age categories reflect the quintile distribution for each condition (the second category forms the baseline). A dummy variable captures the patient's gender (1 = male). We include five Index of Multiple Deprivation (IMD 2004) dummies to control for income deprivation associated with the area in which the patient resides [19]. The 32,482 areas of England were divided into five quintiles according to the proportion of the population experiencing income deprivation, with the first quintile containing the most income deprived areas (the reference group).

We include a dummy variable to reflect whether the patient had been admitted through the emergency department, and two other dummies for whether the patient had been transferred from or to another institution as part of their care pathway. We use the Charlson index [20,21] to account for co-morbidities. Following Street et al. [22], we specify five of the 17 Charlson comorbidities as 'severe', these being renal disease, cancer, moderate or severe liver disease, metastatic solid tumour and AIDS/HIV [20,23] (cerebrovascular disease and hemiplegia/paraplegia were ignored for the stroke analyses as these diagnoses are directly related to stroke itself). The other 12 Charlson comorbidities are designated 'non-severe'. We then define a dummy variable indicating whether the patient suffered from a single non-severe comorbidity and another dummy variable indicating at least one severe or two non-severe comorbidities.

For stroke patients, we account for a secondary diagnosis for pneumonia (ICD-10 J13-J18, J69) [23]. Where multiple diagnoses are recorded, we prioritise ICD-10 I61 (intracerebral haemorrhage) over both ICD-10 I63 (cerebral infarction) and ICD-10 I64 (unspecified stroke), and I63 (cerebral infarction, used as the reference group) over I64 (unspecified stroke). We also account for the presence of a secondary diagnosis of hemiplegia or paraplegia (ICD-10 G041, G114, G801, G802, G81, G82, G830, G831, G832, G833, G834, G839), the number of different diagnoses and the number of different procedures performed.

For patients having a hip replacement, we account for whether they suffered a hip fracture, had a partial hip replacement or underwent a revision procedure. For those having hernia repair, we indicate whether or not it was a bilateral repair, or a laparoscopic repair, and whether or not the patient had a mesh implant to encourage skin growth; we also assess whether such patients had a diagnosis of hypertension or connective tissue disorder.

Finally, in the survival model we account for the admission day of the week (baseline Saturday) and for admission at Easter (Good Friday through to Easter Monday), at Christmas (on Christmas Day or Boxing Day) and on any other Bank Holiday.

### 3.2. Hospital-level variables

We include seven hospital level variables. Larger hospitals might have more specialised equipment and/or staff and so, as a proxy for the size of the hospital, we included the hospital's number of acute beds. We proxy capacity constraints using the percentage of acute beds occupied through the year. Dummies reflect whether the hospital was a teaching hospital, a specialist hospital, and/or a hospital located in the London area. We account of the proportion of hospital income derived from PbR in each fiscal year.

## 4. Results

### 4.1. Descriptive statistics

Figs. 1–3 present annual mortality and 28-day unconditional readmission rates and trends in LoS for each condition. In-hospital mortality fell from 27.7% in 2002/3 to 22.8% in 2007/8 for stroke patients, while the 28-day readmission rate increased from 6.0% to 7.5%. For hip replacement patients, mortality fell from 4.0% to 3.2% and the readmission rate increased slightly from 7.5% to 7.7%. Mortality for hernia repair patients remained at a very low level throughout the period, falling from 0.18% to 0.15%, while the 28-day readmission rate increased slightly from

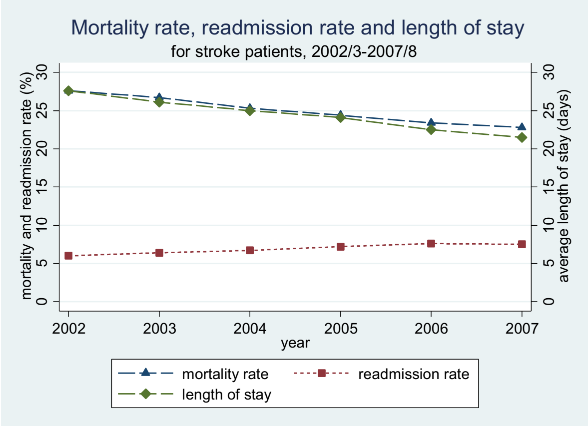


**Fig. 1.** Rates of mortality and, 28-day readmission rates and LoS for stroke patients, 2002/03–2007/08.

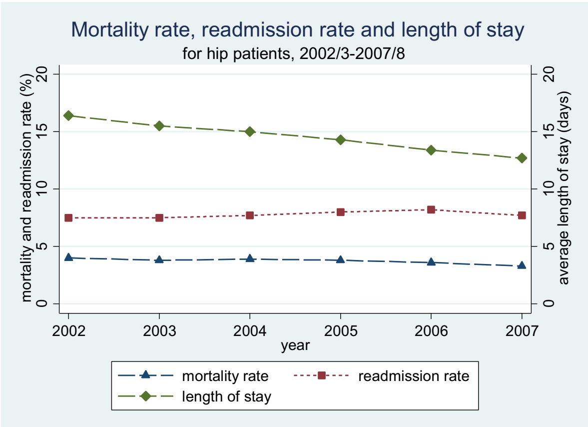


**Fig. 2.** Rates of mortality and 28-day readmission and LoS for hip replacement patients, 2002/03–2007/08.

1.7% to 2.0%. Average LoS for stroke patients fell from 27.6 days in 2002/3 to 21.5 in 2007/8, and it fell from 16.4 to 12.7 for patients having a hip replacement. 44.8% of patients having a hernia repair were treated on a day case basis in 2002/3, increasing to 59.3% in 2007/8.

### *4.1.1. Stroke descriptives*

Descriptive statistics for the stroke patients for the pooled six-year period 2002/03–2007/08 are in Table 1a. Over the six year period, 480,113 stroke patients were admitted to hospital, the annual number falling from 80,815 in 2002/3 to 78,546 in 2007/8. Average age at admission was 75 years, 47% of patients were male, 9% had pneumonia, 13% suffered intracerebral haemorrhage, 55% had a cerebral infarction and for 32% the type of stroke was unspecified (ICD10 I64). The majority (94%) were admitted as emergencies, with 28% being transferred between hospitals. 12% of admissions occurred on Saturday and on Sunday, with around 15% admitted on every other day of the week. 4.9 separate diagnoses were recorded and 0.7 procedures performed per patient.

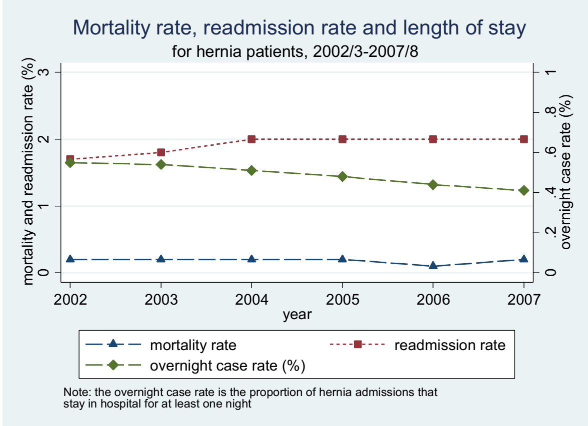


**Fig. 3.** Rates of mortality, 28-day readmission and overnight stays for hernia patients, 2002/03–2007/08.

### *4.1.2. Hip replacement descriptives*

Descriptive statistics for the hip replacement patients for the six-year period 2002/03–2007/08 are in Table 1b. In total 496,334 people had a hip replacement, the number rising from 75,225 in 2002/3 to 91,314 in 2007/8, a clear reflection of the priority afforded to people previously waiting for long periods before being treated [15].

The average age was 73 years, 33% of patients were male, 29% had a partial hip replacement and 12% were undergoing a revision procedure. 37% of patients were admitted as emergencies and 15% were transferred between hospitals. The average patient had 3.7 separate diagnoses recorded and underwent 2.5 procedures.

The way that hospitals schedule hip replacement activity is reflected in variations in the proportions admitted across the week. Patients are most likely to be admitted on Monday to Thursday (16–18% daily) and are much less likely to be admitted on Friday (11%), Saturday (6%) or Sunday (12%).

### *4.1.3. Hernia repair descriptives*

Table 1c shows that 413,712 people had a hernia repair during the six year period, the annual number remaining stable at around 69,000 a year (see Martin et al. [24] for figures for individual years). Less than 0.2% of patients died in hospital while 2% were subsequently readmitted as emergencies.

The average age of a patient was 58 years, and the vast majority (93%) were male. Most (90%) had a unilateral diagnosis, 7.5% had a bilateral diagnosis, 12% had hypertension and 2% had a connective tissue disorder. 10.5% had a laparoscopic repair, this proportion rising from 5.9% in 2002/3 to 16.3% in 2007/8. 83% of patients had a mesh implant to encourage skin growth, the proportions increasing from 80.8% to 84.4% over time. 5% were admitted as emergencies and very few (<1%) were transferred between hospitals. Only 3% of patients were admitted on Saturday or Sunday, with around 19% admitted on Monday to Thursday, and 16% on Friday.

**Table 1**
Descriptive statistics for the variables employed in the regression models, pooled, 2002/03–2007/08.

| (a) Stroke patients | | | (b) Hip replacement patients | | | (c) Hernia repair patients | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Mean | Std. Dev. | Variable | Mean | Std. Dev. | Variable | Mean | Std. Dev. |
| Patient survival dummy | 0.7490 | 0.4336 | Patient survival dummy | 0.9630 | 0.1887 | Patient survival dummy | 0.9984 | 0.0402 |
| Patient re-admission dummy | 0.0923 | 0.2895 | Patient re-admission dummy | 0.0807 | 0.2724 | Patient re-admission dummy | 0.0192 | 0.1372 |
| Length of stay (days) | 24.4955 | 32.5012 | Length of stay (days) | 14.4890 | 17.8088 | Length of stay (=0 if daycase, else = 1) | 0.4860 | 0.4998 |
| Year is 2002, LoS interaction | 4.6385 | 18.2577 | Year is 2002, LoS interaction | 2.4893 | 9.6363 | Year is 2002, LoS interaction | 0.0910 | 0.2876 |
| Year is 2003, LoS interaction | 4.3889 | 17.3284 | Year is 2003, LoS interaction | 2.5188 | 9.4656 | Year is 2003, LoS interaction | 0.0922 | 0.2894 |
| Year is 2004, LoS interaction | 4.2075 | 16.5301 | Year is 2004, LoS interaction | 2.4474 | 9.1976 | Year is 2004, LoS interaction | 0.0839 | 0.2772 |
| Year is 2005, LoS interaction | 4.0572 | 15.7703 | Year is 2005, LoS interaction | 2.3866 | 8.9405 | Year is 2005, LoS interaction | 0.0790 | 0.2697 |
| Year is 2006, LoS interaction | 3.6841 | 14.4768 | Year is 2006, LoS interaction | 2.3137 | 8.5986 | Year is 2006, LoS interaction | 0.0709 | 0.2567 |
| Year is 2007, LoS interaction | 3.5193 | 13.7955 | Year is 2007, LoS interaction | 2.3333 | 8.4345 | Year is 2007, LoS interaction | 0.0690 | 0.2535 |
| Age 1–60 years | 0.1406 | 0.3476 | Age 1–63 years | 0.1961 | 0.3971 | Age 1–42 years | 0.2054 | 0.4040 |
| Age 61–70 years | 0.1612 | 0.3677 | Age 64–71 years | 0.2148 | 0.4107 | Age 43–56 years | 0.2034 | 0.4025 |
| Age 71–80 years | 0.3062 | 0.4609 | Age 72–77 years | 0.1998 | 0.3999 | Age 57–65 years | 0.1998 | 0.3999 |
| Age 81–85 years | 0.1891 | 0.3916 | Age 78–83 years | 0.1948 | 0.3960 | Age 66–74 years | 0.1975 | 0.3981 |
| Age over 86 years | 0.2029 | 0.4021 | Age over 84 years | 0.1945 | 0.3958 | Age over 75 years | 0.1940 | 0.3954 |
| Actual age (years) | 74.7919 | 13.4529 | Actual age (years) | 73.0824 | 12.0018 | Actual age (years) | 57.9883 | 18.1506 |
| Male | 0.4718 | 0.4992 | Male | 0.3346 | 0.4718 | Male | 0.9276 | 0.2592 |
| Charlson index = 0 | 0.6094 | 0.4879 | Charlson index = 0 | 0.7224 | 0.4478 | Charlson index = 0 | 0.8891 | 0.3141 |
| Charlson index = 1 | 0.2545 | 0.4356 | Charlson index = 1 | 0.1954 | 0.3965 | Charlson index = 1 | 0.0886 | 0.2841 |
| Charlson index = 2 | 0.1361 | 0.3429 | Charlson index = 2 | 0.0822 | 0.2747 | Charlson index = 2 | 0.0224 | 0.1479 |
| Pneumonia | 0.0901 | 0.2864 | Hip fracture dummy | 0.2963 | 0.4566 | Inguinal hernia: bilateral diagnosis | 0.0750 | 0.2634 |
| Intracerebral haemorrhage | 0.1328 | 0.3394 | Partial hip replacement | 0.2898 | 0.4537 | Inguinal hernia: other diagnosis | 0.0328 | 0.1781 |
| Cerebral infarction | 0.5460 | 0.4979 | Revision dummy | 0.1215 | 0.3268 | Comorbid: hypertension dummy | 0.1244 | 0.3300 |
| Unspecified stroke | 0.3212 | 0.4670 | Emergency | 0.3711 | 0.4831 | Comorbid: connective tissue disorder | 0.0225 | 0.1482 |
| Emergency | 0.9440 | 0.2298 | Patient dies | 0.0370 | 0.1887 | Laparoscopic repair | 0.1047 | 0.3062 |
| Patient dies | 0.2510 | 0.4336 | Transfer in | 0.0280 | 0.1651 | Presence of implant | 0.8291 | 0.3764 |
| Transfer in | 0.0779 | 0.2680 | Transfer out | 0.1222 | 0.3275 | Emergency | 0.0510 | 0.2199 |
| Transfer out | 0.1981 | 0.3985 | No. of diagnoses | 3.6630 | 2.6666 | Patient dies | 0.0016 | 0.0402 |
| Hemi/paraplegia | 0.0805 | 0.2720 | No. of procedures | 2.5393 | 1.1276 | Transfer in | 0.0029 | 0.0539 |
| No. of diagnoses | 4.9203 | 3.0470 | | | | Transfer out | 0.0039 | 0.0626 |
| No. of procedures | 0.7356 | 1.3680 | | | | No. of diagnoses | 1.7673 | 1.3363 |
| | | | | | | No. of procedures | 2.2502 | 0.6481 |

**Table 1** (*Continued* )

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| IMD Quintile 1 | 0.2050 | 0.4037 | IMD Quintile 1 | 0.1417 | 0.3487 | IMD Quintile 1 | 0.1615 | 0.3680 |
| IMD Quintile 2 | 0.2450 | 0.4301 | IMD Quintile 2 | 0.2232 | 0.4164 | IMD Quintile 2 | 0.2223 | 0.4158 |
| IMD Quintile 3 | 0.2096 | 0.4070 | IMD Quintile 3 | 0.2258 | 0.4181 | IMD Quintile 3 | 0.2154 | 0.4111 |
| IMD Quintile 4 | 0.1829 | 0.3866 | IMD Quintile 4 | 0.2162 | 0.4117 | IMD Quintile 4 | 0.2103 | 0.4075 |
| IMD Quintile 5 | 0.1443 | 0.3513 | IMD Quintile 5 | 0.1799 | 0.3841 | IMD Quintile 5 | 0.1852 | 0.3885 |
| IMD quintile unknown | 0.0132 | 0.1141 | IMD unknown | 0.0133 | 0.1145 | IMD unknown | 0.0053 | 0.0729 |
| Sunday admission | 0.1189 | 0.3237 | Sunday admission | 0.1214 | 0.3266 | Sunday admission | 0.0310 | 0.1733 |
| Monday admission | 0.1593 | 0.3660 | Monday admission | 0.1793 | 0.3836 | Monday admission | 0.1920 | 0.3939 |
| Tuesday admission | 0.1537 | 0.3607 | Tuesday admission | 0.1765 | 0.3813 | Tuesday admission | 0.1941 | 0.3955 |
| Wednesday admission | 0.1488 | 0.3559 | Wednesday admission | 0.1825 | 0.3862 | Wednesday admission | 0.1941 | 0.3955 |
| Thursday admission | 0.1488 | 0.3559 | Thursday admission | 0.1652 | 0.3713 | Thursday admission | 0.1997 | 0.3998 |
| Friday admission | 0.1478 | 0.3549 | Friday admission | 0.1111 | 0.3143 | Friday admission | 0.1632 | 0.3695 |
| Saturday admission | 0.1228 | 0.3282 | Saturday admission | 0.0640 | 0.2448 | Saturday admission | 0.0259 | 0.1589 |
| Christmas admission | 0.0046 | 0.0679 | Christmas admission | 0.0026 | 0.0507 | Christmas admission | 0.0002 | 0.0152 |
| Easter admission | 0.0051 | 0.0713 | Easter admission | 0.0034 | 0.0579 | Easter admission | 0.0010 | 0.0315 |
| Bank holiday admission | 0.0098 | 0.0984 | Other bank holiday admission | 0.0104 | 0.1013 | Other bank holiday admission | 0.0028 | 0.0532 |
| No. of acute beds | 767.3817 | 397.2963 | No. of acute beds | 718.9439 | 388.9446 | No. of acute beds | 743.4867 | 378.7677 |
| Bed occupancy rate | 0.8515 | 0.0566 | Bed occupancy rate | 0.8434 | 0.0621 | Bed occupancy rate | 0.8523 | 0.0572 |
| Teaching hospital | 0.1725 | 0.3778 | Teaching hospital | 0.1291 | 0.3354 | Teaching hospital | 0.1543 | 0.3613 |
| Specialist hospital | 0.0018 | 0.0429 | Specialist hospital | 0.0396 | 0.1949 | Specialist hospital | 0.0013 | 0.0367 |
| London hospital | 0.1239 | 0.3295 | London hospital | 0.1040 | 0.3053 | London hospital | 0.1287 | 0.3349 |
| FCEs s.t. PbR rate | 0.3036 | 0.3605 | FCEs s.t. PbR rate | 0.3314 | 0.3654 | FCEs s.t. PbR rate | 0.3101 | 0.3641 |
| Year is 2002 | 0.1683 | 0.3742 | Year is 2002 | 0.1516 | 0.3586 | Year is 2002 | 0.1649 | 0.3711 |
| Year is 2003 | 0.1680 | 0.3739 | Year is 2003 | 0.1625 | 0.3689 | Year is 2003 | 0.1709 | 0.3764 |
| Year is 2004 | 0.1684 | 0.3742 | Year is 2004 | 0.1629 | 0.3693 | Year is 2004 | 0.1660 | 0.3721 |
| Year is 2005 | 0.1682 | 0.3740 | Year is 2005 | 0.1667 | 0.3727 | Year is 2005 | 0.1660 | 0.3721 |
| Year is 2006 | 0.1635 | 0.3698 | Year is 2006 | 0.1724 | 0.3777 | Year is 2006 | 0.1625 | 0.3689 |
| Year is 2007 | 0.1636 | 0.3699 | Year is 2007 | 0.1840 | 0.3875 | Year is 2007 | 0.1698 | 0.3754 |

*Notes:* (i) the sample size is 480,113 patients for stroke, 496,334 for hip replacement, and 413,712 for hernia repair; and (ii) the patient readmission dummy is conditional on survival.

#### 4.1.4. *Hospital descriptives*

The hospital descriptive statistics vary slightly by condition but in the interests of brevity we focus on those for stroke patients here (see Table 1a). The average number of acute beds per hospital was 767. Average bed occupancy rate was 85%, ranging from 62% to 100%. Just over 17% of patients were in a teaching hospital and 12% were in a London hospital. In 2003/04 just under 2% of hospital activity was subject to PbR and this had increased to 76% by 2007/8.

### 4.2. *Regression analysis*

#### 4.2.1. *Stroke*

The pooled regression results for stroke patients are in Table 2. The first two columns (labelled (1) and (2)) of Table 2 report the average marginal effect and the standard error associated with variables present in the probit survival model. In-hospital mortality following stroke improved year-on-year between 2002/3 and 2007/8 as indicated in Fig. 1 and by the positive time trend on the year coefficients in Table 2 for the model predicting survival following stroke.

Older people are less likely to survive, as are women. There is also a higher probability of dying for patients admitted as emergencies (which is the majority at 94%), for patients with Charlson comorbidities, if the patient suffered from pneumonia or intracerebral haemorrhage or unspecified stroke (the reference group being those with a cerebral infarction), perhaps because the patient died before an accurate diagnosis was made. This is consistent with survival being positively related to the numbers of diagnoses and procedures, with survival determining these numbers rather than vice versa.

Patients living in the most affluent areas have a higher probability of survival. As other studies have demonstrated (e.g. Hauck and Zhao [17]), the probability of dying is significantly higher for stroke patients admitted over the weekend and for those admitted over the Christmas and

**Table 2**
Survival and readmission results for stroke spells, 2002/03–2007/08 pooled.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Variables | Sample selection model probit survival for stroke spells 2002/03–2007/08 average marginal effect | Sample selection model probit survival for stroke spells 2002/03–2007/08 standard error | Sample selection model probit readmission for stroke spells 2002/03–2007/08 average marginal effect | Sample selection model probit readmission for stroke spells 2002/03–2007/08 standard error | No sample selection probit readmission for stroke spells 2002/03–2007/08 average marginal effect | No sample selection probit readmission for stroke spells 2002/03–2007/08 standard error |
| *Patient level variables* | | | | | | |
| Length of stay (days) | | | −0.0002$^{***}$ | [0.000] | −0.0000 | [0.000] |
| year2003, LoS interaction | | | 0.0001 | [0.000] | 0.0000 | [0.000] |
| year2004, LoS interaction | | | 0.0001 | [0.000] | 0.0001 | [0.000] |
| year2005, LoS interaction | | | 0.0001 | [0.000] | 0.0001 | [0.000] |
| year2006, LoS interaction | | | −0.0000 | [0.000] | −0.0000 | [0.000] |
| year2007, LoS interaction | | | 0.0001 | [0.000] | 0.0001$^{*}$ | [0.000] |
| Age 1–60 years | 0.0524$^{***}$ | [0.003] | 0.0040 | [0.003] | 0.0107$^{***}$ | [0.002] |
| Age 71–80 years | −0.0745$^{***}$ | [0.002] | 0.0135$^{***}$ | [0.003] | −0.0055$^{***}$ | [0.001] |
| Age 81–85 years | −0.1531$^{***}$ | [0.003] | 0.0362$^{***}$ | [0.006] | −0.0081$^{***}$ | [0.001] |
| Age over 86 years | −0.2454$^{***}$ | [0.004] | 0.0540$^{***}$ | [0.009] | −0.0165$^{***}$ | [0.002] |
| Male | 0.0316$^{***}$ | [0.001] | −0.0072$^{***}$ | [0.002] | 0.0023$^{**}$ | [0.001] |
| Charlson index = 1 | −0.0584$^{***}$ | [0.002] | 0.0237$^{***}$ | [0.003] | 0.0036$^{***}$ | [0.001] |
| Charlson index = 2 | −0.1663$^{***}$ | [0.003] | 0.0321$^{***}$ | [0.007] | −0.0102$^{***}$ | [0.001] |
| Pneumonia | −0.4339$^{***}$ | [0.005] | 0.1024$^{***}$ | [0.018] | −0.0365$^{***}$ | [0.001] |
| Intracerebral haemorrhage | −0.2335$^{***}$ | [0.004] | 0.0897$^{***}$ | [0.011] | 0.0030 | [0.002] |
| Unspecified stroke | −0.1015$^{***}$ | [0.005] | 0.0297$^{***}$ | [0.004] | −0.0006 | [0.001] |
| Emergency | −0.0747$^{***}$ | [0.008] | 0.0488$^{***}$ | [0.009] | 0.0176$^{***}$ | [0.004] |
| Transfer in | −0.0065 | [0.006] | 0.0245$^{**}$ | [0.009] | 0.0108$^{*}$ | [0.004] |
| Transfer out | | | 0.0296$^{***}$ | [0.008] | 0.0525$^{***}$ | [0.007] |
| Hemi/paraplegia | 0.0223$^{***}$ | [0.005] | −0.0110$^{**}$ | [0.004] | −0.0048$^{*}$ | [0.002] |
| No. of diagnoses | 0.0107$^{***}$ | [0.001] | 0.0014$^{*}$ | [0.001] | 0.0024$^{***}$ | [0.000] |
| No. of procedures | 0.0046$^{***}$ | [0.001] | −0.0005 | [0.001] | −0.0001 | [0.001] |
| IMD Quintile 2 | 0.0019 | [0.002] | −0.0063$^{*}$ | [0.002] | −0.0039$^{**}$ | [0.001] |
| IMD Quintile 3 | 0.0047 | [0.003] | −0.0153$^{***}$ | [0.003] | −0.0088$^{***}$ | [0.002] |
| IMD Quintile 4 | 0.0034 | [0.003] | −0.0185$^{***}$ | [0.003] | −0.0108$^{***}$ | [0.002] |
| IMD Quintile 5 (least deprived) | 0.0111$^{**}$ | [0.003] | −0.0243$^{***}$ | [0.003] | −0.0127$^{***}$ | [0.002] |
| IMD Unknown | 0.0495$^{***}$ | [0.007] | −0.0932$^{***}$ | [0.008] | −0.0474$^{***}$ | [0.004] |
| Sunday admission | −0.0004 | [0.002] | | | | |
| Monday admission | 0.0205$^{***}$ | [0.002] | | | | |
| Tuesday admission | 0.0185$^{***}$ | [0.002] | | | | |
| Wednesday admission | 0.0175$^{***}$ | [0.002] | | | | |
| Thursday admission | 0.0132$^{***}$ | [0.002] | | | | |
| Friday admission | 0.0148$^{***}$ | [0.002] | | | | |
| Christmas admission | −0.0328$^{***}$ | [0.009] | | | | |
| Easter admission | −0.0218$^{**}$ | [0.008] | | | | |
| Other bank holiday admission | −0.0218$^{***}$ | [0.006] | | | | |
| *Hospital level variables* | | | | | | |
| No. of acute beds | 0.0000 | [0.000] | 0.0000$^{*}$ | [0.000] | 0.0000$^{*}$ | [0.000] |
| Bed occupancy rate | −0.0049 | [0.046] | 0.0177 | [0.043] | 0.0006 | [0.026] |
| Teaching hospital | 0.0195$^{**}$ | [0.006] | −0.0076 | [0.007] | −0.0002 | [0.005] |
| Specialist hospital | 0.0652$^{**}$ | [0.021] | −0.0096 | [0.021] | 0.0052 | [0.009] |
| London hospital | 0.0275$^{***}$ | [0.007] | 0.0111 | [0.008] | 0.0121$^{*}$ | [0.005] |
| FCEs s.t. PbR rate | 0.0051 | [0.008] | −0.0077 | [0.008] | −0.0033 | [0.005] |
| year2003 | 0.0089$^{***}$ | [0.002] | 0.0020 | [0.004] | 0.0031 | [0.002] |
| year2004 | 0.0177$^{***}$ | [0.003] | 0.0032 | [0.006] | 0.0062$^{*}$ | [0.003] |
| year2005 | 0.0239$^{***}$ | [0.004] | 0.0067 | [0.007] | 0.0097$^{*}$ | [0.004] |
| year2006 | 0.0290$^{***}$ | [0.005] | 0.0147 | [0.009] | 0.0167$^{**}$ | [0.006] |
| year2007 | 0.0299$^{***}$ | [0.006] | 0.0076 | [0.008] | 0.0132$^{**}$ | [0.005] |
| Observations | 480,113 | | 480,113 | | 480,113 | |

*Notes:* (i) $^{***}$ $p < 0.001$, $^{**}$ $p < 0.01$, $^{*}$ $p < 0.05$; (ii) rho = −0.425 (SE = 0.056); (iii) Wald test of in dep. eqns. (rho = 0): chi2(1) = 42.79 Prob > chi2 = 0.0000; (iv) all standard errors are estimated with clustering by hospital.

Easter holiday periods as well as on other Bank Holidays. The probability of survival is higher for patients treated in teaching, specialist and London hospitals but the proportion of activity subject to PbR does not affect the probability of survival.

Having conditioned on the probability of surviving the original hospital admission, column 3 of Table 2 reports the average marginal effect of those factors associated with the probability of being readmitted within 28 days of discharge. This probability increases with age and is slightly higher for women than men. There is a clear socio-economic gradient, with the probability of readmission decreasing as income deprivation falls: for those patients living in the least deprived areas the probability is 0.0243 lower than for someone living in the most deprived areas (ceteris paribus).

The probability of readmission is also higher for people with more Charlson co-morbidities, for those with a diagnosis of pneumonia or intracerebral haemorrhage or unspecified stroke, and for those originally admitted as emergencies or who were subject to a hospital transfer. The number of diagnoses recorded during the original admission tend has a significant positive effect on the probability of readmission. Those originally admitted to larger hospitals have a higher probability of readmission. The average marginal effect is very small, the probability increasing by only 0.0000166 for each extra acute bed.

Fig. 1 and the model without sample selection (column 5 of Table 2) suggest an increasing trend in readmissions over time. But this is (in part) driven by improvements in survival. When these are taken into account, the increase in the probability of being readmitted in 2007/08 compared to 2002/3 is no longer significant.

In keeping with the "quicker and sicker" argument, patients with a longer LoS are less likely to be subsequently readmitted, even having conditioned on the probability of surviving the original admission (AME = −0.0002285). Notably, this significant effect is not identified unless sample selection is accounted for. The interaction terms of LoS and year were not significant, indicating that the relationship between LoS and the probability of readmission has not been affected by general reductions in LoS.

### 4.2.2. *Hip replacement*

Survival following hip replacement has improved over time, with in-hospital mortality falling from 4.0% in 2002/3 to 3.2% in 2007/8, as shown in Fig. 2. Unlike for stroke, survival proved unrelated to the day of admission, rendering the proposed identification strategy invalid for this condition. Consequently, readmissions following hip replacement are reported in Table 3 without conditioning on survival.

Older patients and men face a higher probability of being readmitted within 28 days of discharge. There is also a socio-economic gradient, with those from the most deprived communities facing a higher probability of readmission. The probability of readmission is also higher for those originally admitted as an emergency, for those with a non-severe Charlson co-morbidity and with more recorded diagnoses. The probability is lower for those who suffered a hip fracture but higher for those who had a revision.

**Table 3**
Readmission results for hip replacement spells, 2002/03–2007/08 pooled.

| | (1) | (2) |
|---|---|---|
| Variables | No sample selection probit readmission for hip spells 2002/03–2007/08 average marginal effect | No sample selection probit readmission for hip spells 2002/03–2007/08 standard error |
| *Patient level variables* | | |
| Length of stay (days) | −0.0000 | [0.000] |
| year2003, LoS interaction | −0.0001 | [0.000] |
| year2004, LoS interaction | 0.0000 | [0.000] |
| year2005, LoS interaction | 0.0000 | [0.000] |
| year2006, LoS interaction | −0.0000 | [0.000] |
| year2007, LoS interaction | 0.0002* | [0.000] |
| Age 1–63 years | −0.0064*** | [0.001] |
| Age 72–77 years | 0.0075*** | [0.001] |
| Age 78–83 years | 0.0149*** | [0.001] |
| Age over 84 years | 0.0195*** | [0.002] |
| Male | 0.0116*** | [0.001] |
| Charlson index = 1 | 0.0144*** | [0.001] |
| Charlson index = 2 | −0.0106*** | [0.002] |
| Hip fracture dummy | −0.0276*** | [0.002] |
| Partial hip replacement DV | −0.0072*** | [0.002] |
| Revision dummy | 0.0237*** | [0.002] |
| Emergency | 0.0467*** | [0.002] |
| Transfer in | 0.0109 | [0.007] |
| Transfer out | 0.0020 | [0.006] |
| No. of diagnoses | 0.0019*** | [0.000] |
| No. of procedures | 0.0001 | [0.001] |
| IMD Quintile 2 | −0.0040** | [0.001] |
| IMD Quintile 3 | −0.0090*** | [0.001] |
| IMD Quintile 4 | −0.0144*** | [0.002] |
| IMD Quintile 5 | −0.0133*** | [0.002] |
| IMD Unknown | −0.0507*** | [0.004] |
| *Hospital level variables* | | |
| No. of acute beds | 0.0000 | [0.000] |
| Bed occupancy rate | −0.0258 | [0.016] |
| Teaching hospital | 0.0014 | [0.004] |
| Specialist hospital | −0.0048 | [0.007] |
| London hospital | −0.0041 | [0.003] |
| FCE s.t. PbR rate | −0.0004 | [0.004] |
| year2003 | 0.0010 | [0.002] |
| year2004 | 0.0007 | [0.003] |
| year2005 | 0.0021 | [0.003] |
| year2006 | 0.0059 | [0.004] |
| year2007 | −0.0018 | [0.004] |
| Observations | 496,334 | |

*Notes:* (i) *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$; (ii) standard errors are estimated with clustering by hospital.

No hospital characteristics are related to the probability of readmission.

Readmission rates exhibit no significant temporal trend and there is no association between LoS and readmission.

### 4.2.3. *Hernia repair*

Given that the likelihood of dying in hospital is so low following admission for hernia repair, it proved unnecessary to account for the probability of survival when analysing readmissions. As reported in Table 4, the probability of readmission increases with age, is greater for men, and is higher for people living in areas of greater income deprivation, for those originally admitted as an emergency and for those with more diagnoses and procedures.

**Table 4**
Readmission results for hernia repair spells, 2002/03–2007/08 pooled.

| | (1) | (2) |
|---|---|---|
| Variables | No sample selection probit readmission for hernia spells 2002/03–2007/08 average marginal effect | No sample selection probit readmission for hernia spells 2002/03–2007/08 standard error |
| *Patient level variables* | | |
| Length of stay (=1 if overnight, else = 0) | 0.0304*** | [0.002] |
| year2003, LoS interaction | −0.0003 | [0.003] |
| year2004, LoS interaction | −0.0005 | [0.003] |
| year2005, LoS interaction | −0.0037 | [0.002] |
| year2006, LoS interaction | 0.0005 | [0.003] |
| year2007, LoS interaction | −0.0003 | [0.002] |
| Age 1–42 years | 0.0009 | [0.001] |
| Age 57–65 years | 0.0013 | [0.001] |
| Age 66–74 years | 0.0046*** | [0.001] |
| Age over 75 years | 0.0114*** | [0.001] |
| Male | 0.0033*** | [0.001] |
| Charlson index = 1 | 0.0013 | [0.001] |
| Charlson index = 2 | −0.0035*** | [0.001] |
| Inguinal hernia: bilateral diagnosis | 0.0019** | [0.001] |
| Inguinal hernia: other diagnosis | −0.0015 | [0.001] |
| Comorbidity: hypertension dummy | −0.0031*** | [0.001] |
| Comorbidity: connective tissue issue | −0.0023* | [0.001] |
| Laparoscopic repair | −0.0001 | [0.001] |
| Presence of implant | −0.0029*** | [0.001] |
| Emergency | 0.0145*** | [0.001] |
| Transfer in | 0.0037 | [0.003] |
| Transfer out | 0.0082** | [0.003] |
| No. of diagnoses | 0.0025*** | [0.000] |
| No. of procedures | 0.0011*** | [0.000] |
| IMD Quintile 2 | −0.0034*** | [0.001] |
| IMD Quintile 3 | −0.0037*** | [0.001] |
| IMD Quintile 4 | −0.0057*** | [0.001] |
| IMD Quintile 5 | −0.0058*** | [0.001] |
| IMD Unknown | −0.0110*** | [0.001] |
| *Hospital level variables* | | |
| No. of acute beds | 0.0000 | [0.000] |
| Bed occupancy rate | 0.0001 | [0.006] |
| Teaching hospital | 0.0005 | [0.001] |
| Specialist hospital | −0.0006 | [0.004] |
| London hospital | −0.0023** | [0.001] |
| FCEs s.t. PbR rate | −0.0019 | [0.002] |
| year2003 | 0.0014 | [0.003] |
| year2004 | 0.0042 | [0.003] |
| year2005 | 0.0097** | [0.004] |
| year2006 | 0.0060 | [0.003] |
| year2007 | 0.0079* | [0.003] |
| Observations | 413,712 | |

*Notes:* (i) *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$; (ii) standard errors are estimated with clustering by hospital.

Compared to those with a unilateral or unspecified inguinal hernia, the likelihood of readmission is higher for those with a bilateral inguinal hernia diagnosis but lower for those with a diagnosis of hypertension, connective tissue disorder and those who had a mesh implant.

Of the hospital level variables, only admission to a London hospital has a significant effect on the probability of readmission and this is a negative effect. There is no clear trend in readmission rates over time.

Those patients who had an overnight stay were significantly more likely to be readmitted (AME = 0.0304), a finding which appears to contradict the “quicker and sicker” argument. This might be because overnight cases are more complex/severe than day cases and that our measures of severity/complexity do not fully capture this.

## 5. Discussion

Hospitals under pressure to reduce costs may do so by reducing LoS, which might have a knock-on adverse effect on quality, one measure of which is emergency readmission within 28 days of discharge. Previous studies have not found a definitive relationship between LoS and subsequent readmission, but those analyses have suffered a weakness in not conditioning on the probability that patients survive the initial admission. We rectify this deficiency by adopting the empirical strategy proposed by Laudicella et al. [14], to analyse three conditions that differ markedly in terms of their baseline LoS, mortality and readmission rates. The strategy involves analysing readmission by first conditioning on the probability of surviving the original admission, and requires identifying a variable that explains survival but not readmission. Laudicella et al. suggest using weekend admission as an identifying variable, as this is predictive of surviving the original admission but not of whether or not the patient will be subsequently readmitted.

Laudicella et al. applied their approach to those who suffered hip fracture and similarly we found that, for stroke patients, survival is significantly lower for those admitted on weekends (or over Christmas, at Easter, or on another public holiday) than for those admitted on weekdays. Hence, we were able to employ the same strategy as Laudicella et al. [14] in analysing readmissions for stroke patients. The greater mortality risk associated with weekend admission following stroke adds to the evidence from other studies that the quality of treatment for some acute admissions is sensitive to the availability of appropriate staff [17]. Stroke patients require immediate diagnosis and appropriate treatment (e.g. to thin or thicken the blood) if their survival chances are not to be adversely affected. Thus we would expect to see a ‘weekend effect’ for conditions where rapid treatment is important.

In contrast, the survival of hip replacement and hernia repair patients will not be materially affected if appropriate treatment is not undertaken on the day of admission and, accordingly, we find no weekend effect for these patients. This means that the Laudicella et al. identification strategy cannot be employed in order to condition on survival in analysing readmissions and further research is required to identify valid exclusion restrictions. For those treatments where mortality is very low, such as hernia repair, it is unnecessary to control for survival when estimating readmissions. For both hip replacement and hernia repair, we report readmission results that do not condition on survival.

The fact that, for some conditions, weekend admission is associated with higher mortality risk is of policy concern in its own right, leading to calls that hospitals offer a more comprehensive seven-day service of the same quality throughout the week [25]. This implies increasing weekend cover, with more senior doctors on duty, together with a full range of diagnostic and support services [25], though questions have been raised about whether this is the most cost-effective way to reduce in-hospital mortality [26].

For none of the conditions did we find that reductions in LoS across the period as a whole were related to an increase in the probability of readmission. However, and consistent with the "quicker and sicker" argument, the probability of readmission was greater for stroke patients who originally had a shorter LoS, this probability remaining unchanged in the face of reductions in LoS. Of importance analytically, it is notable that this significant relationship between LoS and readmission was only evident after conditioning on the probability of surviving the original admission–the model without sample selection suggests no relationship between readmission and LoS of the original admission. The fact that this insight would otherwise be missed provides further support for the Laudicella et al. approach in analysing readmissions to hospitals. The policy importance of this finding is that reductions in LoS in excess of general trends for stroke patients may have adverse consequences on health status, increasing the risk of subsequent readmission. In view of this, it may be unwise to exert excessive pressure to reduce LoS for these patients.

We found no relationship between LoS and readmission for patients who had hip replacement, even though there was a 22% reduction in average LoS for such patients over the period. In contrast to "quicker and sicker" expectations, those hernia repair patients who originally had an overnight stay were more likely to be readmitted. That said the LoS and year interaction terms do not suggest that trends towards undertaking more of this activity on a day case basis were generally associated with increases in readmissions.

The probability of readmission is higher for men and increases with age and severity or complexity. There is also a significant deprivation gradient associated with the probability of readmission for all three conditions, with patients from more affluent areas less likely to be readmitted to hospital. This finding may reflect local socio-economic conditions, including income, housing quality and lifestyle choices, which are not within the control of the local health services, but may also be related to the availability and quality of after-hospital care. Further research is required to understand why this deprivation gradient appears and to take policy steps to reduce it, perhaps by improving immediate after-hospital care in the most deprived areas.

We found that no hospital characteristics were related to the probability of readmission (although the probability of survival following a stroke was higher for patients treated in teaching, specialist and London hospitals). Nor did we find evidence that the proportion of hospital income derived from PbR had an effect on the probability of readmission, a finding consistent with that of Farrar et al. [16]. This suggests that hospitals did not react to the progressive change in their funding arrangements in ways that had adverse impacts on quality. There may be various explanations for this, including the absence of a trade-off between cost and quality, price signals being weak, or hospitals deliberately avoiding strategies when responding to a different financial regime that may have had adverse quality consequences.

The situation observed over the study period may no longer obtain. On the one hand, recent developments in hospital funding, such as best practice tariffs, have provided direct incentives to improve quality. On the other, the analysis was conducted for a period in which overall NHS budgets were being increased, reducing the financial pressure on many hospitals. Nowadays budget increases are flatter and significant productivity improvements are being required of the health care sector; these factors may exert negative pressure on the quality of service provision. Continued analysis of quality will be critical in detecting whether this pressure has had adverse implications on quality so that corrective measures can be implemented.

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