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Increased orthogeriatrician involvement in hip fracture care and its impact on mortality in England

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Author contributions

All authors took part in the design of the study and interpretation of the results. JN and CC drafted the article. JN, JvdM and BDS designed the analysis. All authors revised the article.

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Conflicts of interest

CT and DC are currently commissioned by the Royal College of Physicians to analyze data for the NHFD annual reports as part of the Falls and Fragility Fractures Audit Programme. RW and AJ are the clinical leads for orthopedic surgery and geriatric medicine respectively on the NHFD.

ABSTRACT

Objectives: To describe the increase in orthogeriatrician involvement in hip fracture care in England and its association with improvements in time to surgery and mortality.

Study design: Analysis of Hospital Episode Statistics for 196,401 patients presenting with hip fracture to 150 hospitals in England between 1st April 2010 and 28th February 2014, combined with data on orthogeriatrician hours from a national organisational survey.

Methods: We examined changes in the average number of hours worked by orthogeriatricians in orthopaedic departments per patient with hip fracture, and their potential effect on mortality within 30 days of presentation. The role of prompt surgery (on day of or day after presentation) was explored as a potential confounding factor. Associations were assessed using conditional Poisson regression models with adjustment for patients' sex, age and comorbidity and year, with hospitals treated as fixed effects.

Results: Between 2010 and 2013, there was an increase of 2.5 hours per patient in the median number of hours worked by orthogeriatricians - from 1.5 to 4.0 hours. An increase of 2.5 hours per patient was associated with a relative reduction in mortality of 3.4% (95% confidence interval 0.9% to 5.9%, p = 0.01). This corresponds to an absolute reduction of approximately 0.3%. Higher numbers of orthogeriatrician hours were associated with higher rates of prompt surgery, but were independently associated with lower mortality.

Conclusion: In the context of initiatives to improve hip fracture care, we identified statistically significant and robust associations between increased orthogeriatrician hours per patient and reduced 30-day mortality.

Key words: hip fracture; orthogeriatrics; mortality.

Introduction

Older people who fall and fracture a hip are often frail with multiple health problems. In the UK in 2014, their average age was 83, and just over a fifth were aged 90 years or older.[1] Cognitive problems and comorbidities such as hypertension, heart disease and diabetes are common. Hip fracture causes severe pain and immobility, which can precipitate a rapid decline in fitness and complications such as pressure ulcers and pneumonia.[2] In England, around a third of people die within a year of a hip fracture, and 8-10% die within 30 days.[3]

Orthogeriatrics is a subspecialty that has developed to improve outcomes of older people with fractures by providing medical care alongside orthopaedic surgeons within multidisciplinary teams. Orthogeriatricians provide specialist medical support and a holistic approach to care.[4] In addition, orthogeriatricians often initiate and lead the development of protocols and practices to improve collaboration between surgeons, anaesthetists, nurses, physiotherapists and occupational therapists to provide better pain relief, prompt surgery and effective rehabilitation.

Compared to surgeon-delivered care alone, orthogeriatric care adds reductions in medical complications and mortality, and also improves mobility and independence.[5-7] A meta-analysis including 18 studies (9,094 patients) concluded that multidisciplinary care involving an orthopaedic surgeon and a geriatrician reduced in-hospital mortality and mortality at 6-12 months.[8] In 2011, the National Institute for Health and Care Excellence (NICE) summarised evidence for an orthogeriatrician-led “hip fracture programme”, concluding that it improved mortality, length of stay and long-term dependency, making such an approach cost-saving.[9] Since then, a further Norwegian study has showed how orthogeriatric care delivered on a dedicated ward can improve mobility, activities of daily living and cost-effectiveness. [10]

Orthogeriatric models of care have been widely adopted within the UK. A collaboration between an orthopaedic surgeon and a geriatrician was first developed in Hastings in the 1960s.[11] By 2004, two-fifths of NHS hospitals in England reported involvement of orthogeriatricians in hip fracture care, but only four reported having an orthogeriatrician working full time on the fracture ward.[12] In 2007, the British Geriatrics Society (BGS) and the British Orthopaedic Association

(BOA) published guidance on the care of patients with fragility fractures, specifying access to acute orthogeriatric care and prompt surgery as two of six national clinical standards, and launching the National Hip Fracture Database (NHFD) to support their implementation.[13]

In England, a further sharp rise in orthogeriatrician staffing followed the introduction of financial incentives under the Best Practice Tariff (BPT) scheme in April 2010.[14] The BPT scheme required assessment by a geriatrician within 72 hours and surgery within 36 hours as two of the conditions for additional payment.

Our study addressed the question: has the increased involvement of orthogeriatricians in hip fracture care led to the intended improvements in patient outcomes? We documented trends in numbers of hours worked by orthogeriatricians in orthopaedic departments in England between 2010 and 2013, and then estimated the association between increased hours per patient with hip fracture and 30-day mortality. Finally, we examined the role of prompt surgery (on the day of, or day after presentation with hip fracture) as a potential confounder of the relationship between orthogeriatrician hours and mortality.

Methods

Intervention - orthogeriatrician involvement in hip fracture care

Orthogeriatrician involvement is primarily clinical but can also extend to system change, audit, and leadership of clinical and service development. For this reason, we defined exposure to orthogeriatrician involvement broadly, and estimated it at a hospital level – using the number of hours worked by orthogeriatricians in orthopaedic departments. These data are collected annually via the NHFD Facilities Survey. For each hospital, the average number of hours per patient was estimated by multiplying weekly hours worked by orthogeriatricians by 52 and dividing by the annual number of patients presenting with hip fracture. In a separate analysis, we used the hospital proportion of patients assessed by an orthogeriatrician within 72 hours as an alternative measure of their involvement. The results of this separate analysis, along with further details

about the data used in the main analysis are given in Appendix 1 in the supplementary data available online.

Patient cohort

We identified a cohort of patients admitted to hospital with hip fracture between 1st April 2010 and 28th February 2014 using non-audit data from Hospital Episode Statistics (HES) which covers all NHS hospitals in England.[15] This was linked at individual-level to Office for National Statistics (ONS) data on all registered deaths.[16] HES includes information about patients' diagnoses, coded using the International Classification of Diseases, 10th Revision (ICD-10).

Patients with hip fracture were identified using the ICD-10 codes S72.0 (fracture of neck of femur), S72.1 (pertrochanteric fracture) and S72.2 (subtrochanteric fracture). Records were extracted for all patients aged 60 years or older with a diagnosis of hip fracture in any of 14 diagnosis fields in the first record (episode) of their first admission with hip fracture. Records that indicated a planned rather than an emergency admission were excluded.

Individual hospitals were identified in HES using data fields containing the provider and site of treatment. These were matched to hospitals that participated in the NHFD throughout the study period using a spreadsheet available from the NHFD website (http://www.nhfd.co.uk), which was manually checked and corrected. Our final cohort included 196,401 patients admitted with hip fracture to 150 NHS hospitals.

Patient-level variables

Prompt surgery was defined as surgery performed on the day of or day following presentation. This is the NICE clinical guideline, and closely matches 36-hour target that the Best Practice Tariff (BPT) standard. This was calculated using the dates of hospital admission and of first surgery for hip fracture since exact times are not recorded in HES. Procedures are coded using the UK Office for Population Censuses and Surveys (OPCS) version 4. The codes we used included: internal or external fixation (W19, W20, W22, W24); hemiarthroplasty (W46-W48); and total hip replacement (W37-W39; W93-W95).

Mortality was measured at 30 days after hip fracture, including deaths in hospital and in the community, based on the date of death recorded in the HES-ONS linked dataset. The number of comorbidities was measured using a method developed for HES data based on the Charlson Score which includes selected diagnosis codes for present and past admissions within the previous year. [17]

Statistical analyses

For the main analysis, we grouped the HES-ONS patient-level data by age group (60-69 years; 70-79 years; 80-89; and 90 years or older); sex; number of comorbidities (0, 1 or ≥ 2), financial year of admission (2010/11 to 2013/14); and hospital.

The primary outcome variable was 30-day mortality in each group. The average number of orthogeriatrician hours per patient varied by hospital and year, and the relationship between this and mortality was modelled using Poisson regression modelling, with other variables included as additional explanatory variables. Financial year was included to examine annual variation in mortality. To adjust for impacts of variation in hospital hip fracture populations, we included age group, sex and number of comorbidities as categorical explanatory variables. Further between-hospital variations were treated as time-constant differences and modelled using a fixed effects specification of the Poisson model. [18]

Results are presented as relative percentage changes in outcomes, with 95% confidence intervals (CIs) for a 2.5-hour increase in average orthogeriatrician hours per patient, i.e. the increase in median hours per patient we observed between 2010 and 2013. Corresponding absolute changes were calculated using the 2010 rate as a baseline. Full results are given in Appendix 2 in the supplementary data available online. Reported p-values are from 2-sided Wald tests.

We carried out secondary analyses to explore the role of prompt surgery. First, we examined the association between orthogeriatrician hours and prompt surgery as an outcome variable also using fixed effects Poisson regression. Second, we re-examined the association between

orthogeriatrician hours and mortality, adjusting for prompt surgery as a binary explanatory variable. We restricted these analyses to patients who had surgery.

Results

Trends in orthogeriatrician hours reported in NHFD Annual Facilities Survey

The median annual number of orthogeriatrician hours per patient with hip fracture increased by 2.5 hours between 2010 and 2013, from 1.5 to 4.0 hours. The percentage of hospitals reporting zero orthogeriatrician hours fell from 8.5% (8/94 hospitals) to 2.0% (3/150 hospitals).

Figure 1 shows the distribution of orthogeriatrician hours per patient across hospitals each year, revealing increasing variation between hospitals over time. In 2013, the inter-quartile range (the difference between the bottom 25% and top 25% of hospitals) was approximately 4.9 hours.

Trends in patients' characteristics, care and mortality after hip fracture

The sex and age breakdown of patients with hip fracture did not change substantially over the study period. The percentage of women decreased from 72.8% to 71.6%, while that of patients aged 90 years or older increased from 20.2% to 21.5%. The percentage of patients with two or more documented comorbidities increased from 30.8% to 36.1% (Table 1).

The percentage of patients who had surgery remained stable at 92.0%. The percentage of these who had prompt surgery (on day of, or day after, admission) increased from 68.2% to 77.3%.

30-day mortality remained relatively stable between 2010/11 and 2012/13 at rates of 8.7% and 8.6% respectively, then falling to 7.9% in 2013/14.

Mortality was 40% lower among women than men. Mortality was four times higher among those aged 90 years or older compared to those aged 60-69 years; and four times higher among those with 2 or more comorbidities than those with none. There was no evidence of a difference in mortality trends by group (see Appendix 2 in supplementary data online).

Relationship between number of orthogeriatrician hours and 30-day mortality

Figure 2 shows that higher numbers of orthogeriatrician hours per patient were associated with lower annual 30-day mortality (Spearman's rank correlation coefficient -0.11, p-value = 0.01).

After adjustment for age, sex and comorbidity, and for annual variation in mortality, the expected relative reduction in mortality for a 2.5-hour per patient increase was 3.4% (95% CI 0.9% to 5.9%, p = 0.01). This corresponds to an absolute reduction of approximately 0.3% for this level of investment in a hospital with a baseline mortality rate of 8.7% (-3.4% x 8.7% ≈ -0.3%).

Relationship between orthogeriatrician hours, prompt surgery and 30-day mortality

Higher orthogeriatrician hours per patient were also associated with higher rates of prompt surgery. After adjustment for patient characteristics and annual variation, the expected relative increase in rates of prompt surgery was 1.3% (95% CI 0.0% to 2.6%, p = 0.05) for a 2.5 hour per patient increase in orthogeriatrician hours. This corresponds to an absolute increase of 0.9% for a hospital with a baseline rate of 68.2% (1.3% x 68.2% ≈ 0.9%).

There was a large and significant association between having prompt surgery and lower 30-day mortality (relative reduction 12.9%, 95% CI 9.5% to 16.2%, p < 0.001; absolute reduction of 0.9% for baseline rate of 8.7%).

However, adjusting for prompt surgery very slightly reduced but did not explain the association between increased orthogeriatrician hours and reduced 30-day mortality (relative reduction 3.0%, 95% CI 0.2% to 5.8%, p=0.03; absolute reduction of 0.26% from baseline rate of 8.7%).

Discussion

Main findings

Over the period 2010 to 2013, we found that higher numbers of orthogeriatrician hours per patient were consistently associated with lower 30-day mortality. This association persisted after adjustment for patient characteristics and annual variation in mortality.

Higher numbers of orthogeriatrician hours were also associated with higher rates of prompt surgery, and there was a strong association at the individual level between having prompt surgery

and lower mortality. However, an independent association between increased orthogeriatrician hours and lower mortality persisted after adjusting for the effects of prompt surgery.

If the association were causal, the 2.5 hour increase in orthogeriatrician hours would equate with the avoidance of nearly 200 deaths within 30 days of hip fracture across the 65,000 people presenting with this injury each year (absolute reduction 0.3% x 65,000 = 195). Even after adjustment for the effects of prompt surgery, it would equate with the avoidance of around 170 deaths per year.

Strengths and limitations of study

This is the first nation-wide study to quantify orthogeriatrician involvement in hip fracture and describe its impact on patient care and outcomes. We used hospital-level data on orthogeriatrician involvement: hours worked by orthogeriatricians in orthopaedic departments reported in an annual organisational survey. We estimated a standardised measure of orthogeriatrician hours per patient with hip fracture as a clear and straightforward approach that would help in defining the job plan or business case for a new post.

There are several potential sources of error in the estimation of hours per patient. One source of error arises from the fact that data on weekly orthogeriatrician hours were collected via an annual survey, so that within-year changes are not captured. In addition, we estimated annual hours by multiplying reported weekly hours by 52, but we recognize that there will be variation in part-time work patterns, sickness leave, annual/study leave, and arrangements for leave cover across different hospitals. Finally, the roles of orthogeriatricians vary between units, with some taking responsibility for all older patients with fractures, and even for older elective orthopaedic surgery patients. Such factors are complex to define even within a department, but they will affect every post in England to some extent, so this lack of standardisation will contribute to measurement error in the exposure. In turn, measurement error in the exposure, if this error is independent of the outcome, will tend to contribute to underestimation of the true association.[16]

We carried out a parallel analysis to check the validity of orthogeriatrician hours per patient as a measure of their involvement in clinical hip fracture care. Orthogeriatrician hours were strongly correlated with the proportion of patients assessed by an orthogeriatrician within 72 hours (Spearman's rank correlation coefficient 0.51, p-value <0.001), as well as with other markers of orthogeriatrician involvement (see Appendix 1 in the supplementary data online).

There was a higher rate of missing data in the 2010 organisational survey; 62.7% of hospitals (94 out of 150) providing complete data compared to 93.3% in 2011, 99.3% in 2012 and 100.0% in 2013. However two sensitivity analyses, one restricted to the years 2011-2013 and the other confined to 89 hospitals with complete data for all 4 years, both confirmed the association between increased orthogeriatrician hours and lower mortality. Given this we chose to report on the whole period 2010-13, since this captures the key investment following the introduction of BPT in April 2010.

Finally, although the contribution of orthogeriatric care is both broad and variable, our study used a limited measure of input (in hours) to measure it. The same number of hours worked by an orthogeriatrician will mask variations in the nature of their involvement, with some services providing continuity of care and others providing a reactive service. A previous qualitative study of four hip fracture services highlighted such variation: in the style and formalization of collaboration; the extent to which multidisciplinary team members engaged with one another through ward rounds and MDT meetings; and in staff perceptions of teamwork.[17]

Orthogeriatrics in the context of quality improvement in hip fracture care

Access to orthogeriatric care is just one component of quality improvement in improve hip fracture care, and increased orthogeriatrician involvement may be both a consequence as well as a driver for wider service improvements. For example, orthogeriatricians may improve care quality by improving the coordination of care, improving standardization of care by introducing protocols and by assessing complex issues in the care of older people such as decisions on the surgical or non-surgical management of the frailest, near-terminal patients. Any more detailed clarification of the

impact of these factors, the impact of standards and audit, the availability of specialist nurses and audit coordinators, and improved multi-disciplinary teamwork would be complex.

Our study was limited to a hospital-level time-based measure of orthogeriatrician involvement. So our estimates represent a combination of individual effects of orthogeriatric assessment and care, averaged over patients who did and did not receive it, plus wider benefits of their involvement in the service. In addition, there is an important interplay between orthogeriatrician, surgeon and anaesthetist in the optimization of patients prior to surgery. Much of this is in the provision of a uniform approach to acceptable criteria for surgery with the adoption of national guidelines.[9,21] Once the patient has been seen by an orthogeriatrician and has been assessed as optimized for surgery, a significant barrier to prompt surgery is removed. Future studies could explore individual and service-level effects of orthogeriatric care, and relationships to prompt surgery, by using linked patient-level data from the NHFD and HES. They could also explore impacts on a wider range of important outcomes documented in NHFD, including restoration of pre-fracture levels of mobility and independence.

Policy implications

The rapid expansion of the subspecialty of orthogeriatrics reflects the strength of its parent specialty, geriatric medicine, within the UK's National Health Service. In other healthcare systems, a comparable expansion of orthogeriatricians may be less likely, with clear consequences for the generalisability of the developments and results this study describes.

Elsewhere, general physicians, internists, physician assistants and senior nurses might, to a greater or lesser extent, fulfil the various roles described for orthogeriatricians, and in some settings this already happens. This could be supported by the use of existing online learning modules covering a range of core orthogeriatric competencies, including the need to adapt treatment in line with ageing, recognition of comorbidities and polypharmacy, early rehabilitation and secondary prevention of osteoporosis and falls.[22]

Key points

- Orthogeriatrician involvement has been a key component of strategies to improve hip fracture care in England
- Increased orthogeriatrician hours in orthopaedic departments are associated with lower 30-day mortality after hip fracture
- Increased hours are also associated with higher rates of prompt surgery, but are independently associated with lower mortality.

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Conflicts of interests

CT and DC are currently commissioned by the Royal College of Physicians to analyse data for the NHFD annual reports as part of the Falls and Fragility Fractures Audit Programme. RW and AJ are the clinical leads for orthopedic surgery and geriatric medicine respectively on the NHFD.

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Table 1 Characteristics of patients admitted with hip fracture and mortality at 30 days by financial year, HES-ONS linked mortality data for 150 hospitals included in study.

	Financial year			
	2010/11	2011/12	2012/13	2013/14
Female	72.8%	73.4%	72.0%	71.6%
Age group				
60-69 years	8.9%	8.7%	9.2%	9.3%
70-79 years	23.1%	22.5%	22.2%	22.2%
80-89 years	47.8%	47.9%	47.1%	46.9%
90 years and older	20.2%	20.9%	21.5%	21.6%
Number of comorbidities†				
None	34.3%	32.7%	31.0%	29.7%
1 comorbidity	34.9%	34.9%	35.1%	34.2%
2 or more comorbidities	30.8%	32.4%	34.0%	36.1%
Surgery	91.7%	92.2%	92.3%	92.4%
of which, prompt surgery	68.2%	72.4%	76.1%	77.3%
30-day mortality	8.7%	8.5%	8.6%	7.9%
Number of patients ‡	48,945	49,784	50,468	47,204 ‡

† Documented comorbidities in HES for current admission and hospital admissions over past year.

‡ The data extract for the financial year 2013/14 was restricted to the 11 months up to 28th February 2014 to allow for 30-day follow up.

Figure 1 Distribution of per-patient hours worked by orthogeriatricians in orthopaedic departments by year; source: NHFD annual facilities survey

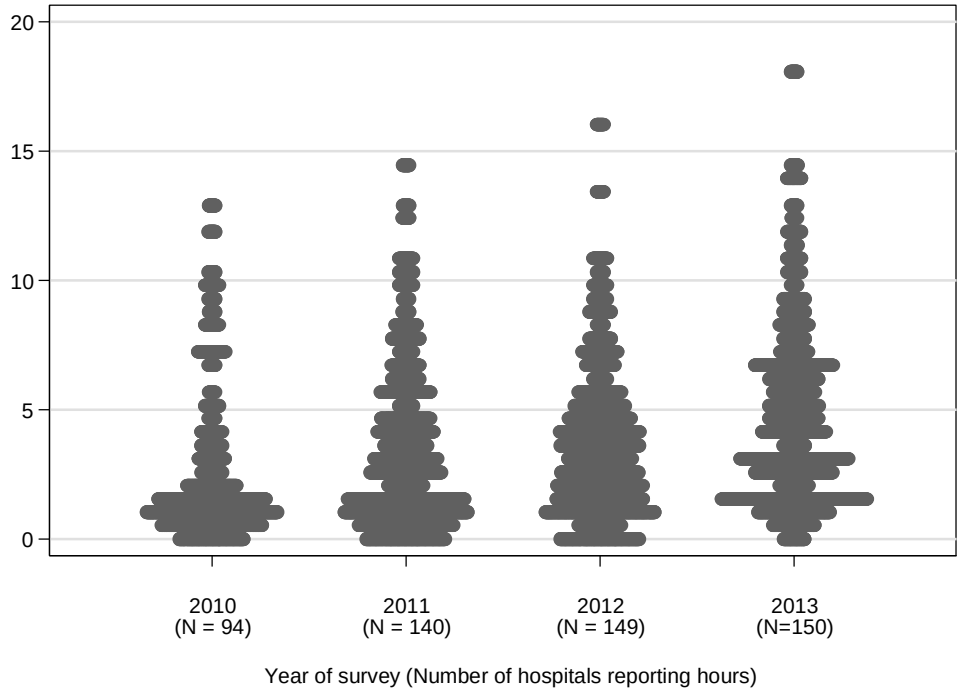
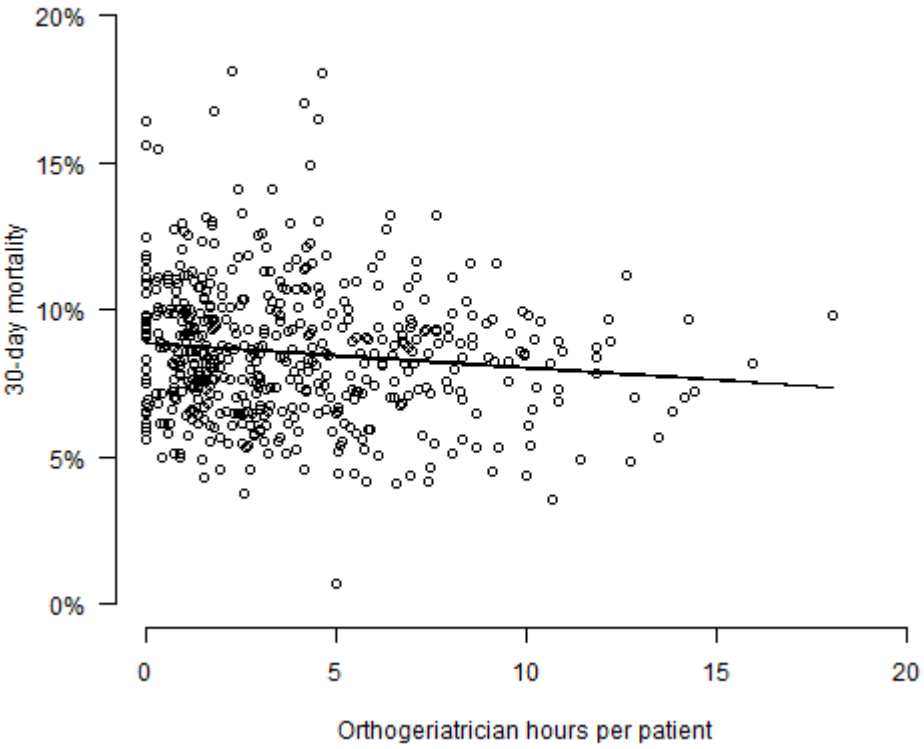


Figure 2 Association between average per-patient hours worked by orthogeriatricians in orthopaedic departments and annual 30-day mortality



SUPPLEMENTARY DATA

Appendix 1 Description and validation of measure of orthogeriatrician involvement

1) Orthogeriatrician hours reported in the NHFD facilities survey

The main measure used in the analysis, orthogeriatrician hours worked in orthopaedic departments per patient admitted with hip fracture, was calculated using two data sources: 1) weekly hours reported for consultant & middle grade orthogeriatricians in the NHFD Facilities Survey; and 2) annual number of patients admitted with hip fracture calculated from Hospital Episode Statistics (HES).

The numerator, weekly hours, was multiplied by 52 and divided by the annual number of patients. The results were robust to denominators calculated from alternative data sources: the NHFD Clinical Audit; and the estimated annual number of hip fracture cases reported in the Facilities Survey. Total weekly hours (numerator) was positively correlated with the annual number of patients admitted with hip fracture (denominator), but the standardised exposure variable (hours per patient) was not.

2) Assessment by an orthogeriatrician documented in NHFD clinical audit

The NHFD is a web-based clinical audit of the process and outcomes of care; using prospectively collected data for all patients presenting with hip fracture in the country. Data on the date and time of assessment by an orthogeriatrician are entered by nurses and audit staff to identify whether individual patient's care meets the criteria for additional Best Practice Tariff. In each hospital, data were aggregated to calculate the annual percentage of patients seen by an orthogeriatrician within 72 hours.

Data fields on the timing of geriatrician assessment and grade of geriatrician were used (Table A1). Patients seen by a geriatrician (consultant, SAS or ST3+ grade) within 72 hours of hospital admission were counted in the numerator. As well as these patients, those not seen by a geriatrician, or seen after 72 hours, were counted in the denominator. Hospital annual rates were set to missing if fewer than 65% of patients within the NHFD had complete data on their time of assessment.

Table A1 Description of NHFD sources used to measure orthogeriatrician involvement

Data source	Field name	Description/Notes	Response format
NHFD Facilities Survey	noofgeriatriconsulthours	Number of hours per week worked by orthogeriatric consultants in the orthopaedic department	Free text
NHFD Facilities Survey	noofgeriatricmghours	Number of hours per week orthogeriatric middle grade doctors work in the orthopaedic department	Free text
NHFD Clinical Audit	4.09 Date & time assessed by geriatrician	Required for BPT	dd/mm/yy hh:mm
NHFD Clinical Audit	4.10 Geriatrician grade	Required for BPT	1. Consultant 2. SAS 3. ST3+ 4. Not seen 5. Unknown

3) Description of missing data

Missing values of geriatrician hours arose where hospitals did not complete the Facilities Survey. Table A2 shows the number and percentage of hospitals with missing data, which fell from 56 (37.3%) to 10 (6.7%) between 2010 and 2011, and to zero by 2013. The probability of a hospital missing hours data was uncorrelated with hospital-level characteristics including: number of patients admitted with hip fracture; % female, % over 90 years of age; % with comorbidities; and 30-day mortality.

Missing values of annual percentages assessed by geriatricians occurred when the data field for time of assessment was poorly completed (<65% complete), or in a few cases where hospitals were not submitting data to the NHFD. The number (%) of hospitals with missing values fell from 42 (28.0%) to 11 (7.3%) between 2010 and

2011, and to zero by 2013. Rates of missing values were slightly higher in hospitals treating fewer patients with hip fracture (based on HES data).

Table A2 Rates of missing data for two measures of orthogeriatrician involvement, annual number (%) out of 150 hospitals

	Orthogeriatrician hours per patient reported in annual facilities survey		Annual % of patients assessed within 72 hours calculated from clinical audit data	
Year	Complete	Missing	Complete	Missing
2010	94 (62.7%)	56 (37.3%)	108 (72.0%)	42 (28.0%)
2011	140 (93.3%)	10 (6.7%)	139 (92.7%)	11 (7.3%)
2012	149 (99.3%)	1 (0.7%)	144 (96.0%)	6 (4.0%)
2013	150 (100.0%)	0 (0.0%)	150 (100.0%)	0 (0.0%)

4) Correlation between alternative measures of orthogeriatrician involvement

We calculated Spearman's rank correlation coefficients to examine associations between pairs of measures of orthogeriatrician involvement, plus their assocaitions with hospital annual rates of prompt surgery (day of, or day after, admission to hospital). Annual hospital-level indicators were calculated directly from hospital-level data collected via the NHFD Facilities Survey, or from aggregated patient-level data from the NHFD Clinical Audit or Hospital Episode Statistics.

The main intervention measure of orthogeriatrician hours per patient was strongly correlated with other measures, including: the annual % of patients assessed by a geriatirican within 72 hours; the number of ward rounds per week (NHFD Facilities Survey), the annual mean number of days on which patients were assessed by a geriatrician each week (NHFD Clinical Audit).

Table A3 Spearman's rank correlation coefficients for associations between pairs of indicators

	a) Hours per patient	b) Annual rate of assessment within 72 hours	c) Number of ward rounds per week	d) Annual mean number of assessment days per week	e) Annual % having prompt surgery
a) Hours per patient	1.00				
b) Annual rate of assessment within 72 hours	0.51***	1.00			
c) Number of ward rounds per week	0.45***	0.45***	1.00		
c) Annual mean number of assessment days per week	0.28***	0.61***	0.45***	1.00	
e) Annual % having prompt surgery	0.24***	0.38***	0.15*	0.17**	1.00

*** p value <0.001 ** p value <0.01 *p value <0.05

Sources of data: a) NHFD Facilities Survey; b) NHFD Clinical Audit; c) NHFD Facillities Survey; d) NHFD Clinical Audit; e) Hospital Episode Statistics.

Appendix 2 Results from different models

In the main paper, we have presented results from conditional Poisson models with mortality (number of deaths per group divided by number of patients per group) as the outcome variable and the average number of orthogeriatrician hours per patient. As described in full in the methods section of the main paper, we included year as a categorical explanatory variable to adjust for time trends; patients' age group, sex and number of comorbidities as potential confounders; and treated hospital as a fixed effect, which is equivalent to including dummy variables for each individual hospital (omitting 1 as a reference).

Table A4 shows the full set of estimated rate ratios from different models including fixed effects and random effects models. The associations of each of the two exposures to mortality were small but statistically significant across all of the models. With orthogeriatrician hours per patient, the estimated association was slightly smaller but more precise for the random effects vs the fixed effects model but each of the estimates lies within the confidence interval of the other estimate. With annual rates of assessment by an orthogeriatrician, the estimated association is unchanged and again slightly more precise for the random effects model.

Table A5 shows results from models exploring the relationships between orthogeriatrician hours, prompt surgery, and 30-day mortality. Table A6 shows results from models with the annual % assessed by a geriatrician within 72 hours as the main intervention variable.

1) Models with interactions

We estimated models including interaction terms to test for differences in mortality time trends by age and sex, and interaction terms to test for differences in the association between orthogeriatrician involvement and mortality by age and sex. There was no evidence that any individual interaction was significant (based on Wald tests), and no evidence that models including interaction terms fitted the data better (based on likelihood ratio tests).

Table A4 Estimated rate ratios (SEs) from five Poisson regression models with 30-day mortality as the outcome: 1) without adjustment for hospital; 2) hospitals treated as fixed effects; 3) hospitals treated as fixed effects and adjustment for other variables but not comorbidity; 4) hospitals treated as fixed effects and adjustment for other variables including comorbidity (MAIN MODEL); and 5) hospitals treated as random effects and adjustment for other variables

	1	2	3	4	5
Orthogeriatrician hours (per 2.5-hour increase per patient)	0.976 (0.006)	0.954 (0.012)	0.972 (0.013)	0.966 (0.013)	0.973 (0.009)
Year (reference = 2010/11)					
2011/12	-	-	0.957 (0.025)	0.940 (0.025)	0.934 (0.024)
2012/13	-	-	0.969 (0.026)	0.934 (0.025)	0.928 (0.024)
2013/14	-	-	0.888 (0.025)	0.837 (0.023)	0.831 (0.022)
Female (reference = male)	-	-	0.541 (0.009)	0.614 (0.011)	0.614 (0.011)
Age group (ref = 60-69 years)					
70-79 years	-	-	1.645 (0.081)	1.415 (0.005)	1.416 (0.070)
80-89 years	-	-	2.774 (0.127)	2.270 (0.104)	2.267 (0.104)
90 years and older	-	-	4.870 (0.226)	3.986 (0.185)	3.976 (0.184)
Number of comorbidities (ref = none)					
1 comorbidity	-	-	-	2.150 (0.060)	2.156 (0.061)
2 or more comorbidities	-	-	-	4.000 (0.105)	3.998 (0.105)

Table A5 Estimated rate ratios (SEs) from Poisson regression models exploring relationship between orthogeriatrician hours, prompt surgery and 30-day mortality: a) Prompt surgery as an outcome; b) 30-day mortality as an outcome and prompt surgery as a binary explanatory variable

	Outcome variable	
	a) Prompt surgery	b) 30-day mortality
Orthogeriatrician hours (per 2.5-hour increase per patient)	1.013 (0.007)	0.970 (0.014)
Prompt surgery (reference = no)	N/A	0.871 (0.018)
Year (reference = 2010/11)		
2011/12	1.056 (0.014)	0.954 (0.028)
2012/13	1.110 (0.015)	0.968 (0.029)
2013/14	1.127 (0.016)	0.871 (0.028)
Female (reference = male)	1.062 (0.010)	0.613 (0.011)
Age group (ref = 60-69 years)		
70-79 years	0.990 (0.016)	1.449 (0.086)
80-89 years	1.009 (0.015)	2.516 (0.139)
90 years and older	1.026 (0.017)	4.648 (0.259)
Number of comorbidities (ref = none)		
1 comorbidity	0.974 (0.010)	2.171 (0.067)
2 or more comorbidities	0.901 (0.010)	3.886 (0.114)

Table A6 Estimated rate ratios (SEs) from five Poisson regression models with 30-day mortality as the outcome: 1) without adjustment for hospital; 2) hospitals treated as fixed effects; 3) hospitals treated as fixed effects and adjustment for other variables but not comorbidity; 4) hospitals treated as fixed effects and adjustment for other variables including comorbidity (MAIN MODEL); and 5) hospitals treated as random effects and adjustment for other variables

	1	2	3	4	5

Annual % receiving assessment within 72 hours (per 12.5% increase)	0.974 (0.005)	0.966 (0.009)	0.972 (0.010)	0.973 (0.010)	0.974 (0.008)
Year (reference = 2010/11)					
2011/12	-	-	0.975 (0.239)	0.957 (0.023)	0.955 (0.023)
2012/13	-	-	1.002 (0.026)	0.963 (0.025)	0.960 (0.024)
2013/14	-	-	0.917 (0.026)	0.861 (0.024)	0.856 (0.022)
Female (reference = male)	-	-	0.545 (0.009)	0.617 (0.010)	0.618 (0.010)
Age group (ref = 60-69 years)					
70-79 years	-	-	1.634 (0.080)	1.407 (0.069)	1.409 (0.069)
80-89 years	-	-	2.744 (0.124)	2.247 (0.102)	2.247 (0.102)
90 years and older	-	-	4.867 (0.222)	3.992 (0.183)	3.987 (0.183)
Number of comorbidities (ref = none)					
1 comorbidity	-	-	-	2.179 (0.061)	2.185 (0.061)
2 or more comorbidities	-	-	-	4.010 (0.105)	4.019 (0.105)