The influence of hospital-level variables on hip fracture outcomes

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Abstract

Aims:

To determine the impact of hospital-level service characteristics on hip fracture outcomes and quality of care processes measures.

Materials & Methods:

Retrospective analysis of publicly available audit data obtained from the National Hip Fracture Database (NHFD) 2018 benchmark summary and Facilities Survey. Data extraction was performed using a dedicated proforma to identify relevant hospital-level care process and outcome variables for inclusion. The primary outcome measure was adjusted 30-day mortality rate. A random forest-based multivariate imputation by chained equation (MICE) algorithm was utilised for missing value imputation. Univariable analysis for each hospital level factor was performed using a combination of Tobit regression, Siegal non-parametric linear regression and Mann-Whitney U analyses, dependent on the data type. In all analyses $p<0.05$ denoted statistical significance.

Results:

Analyses included 176 hospitals, with a median of 366 hip fracture cases per year. Aggregated data from 66,578 patients were included. The only identified hospital-level variable associated with the primary outcome of 30-day mortality was hip fracture trial involvement (Mann Whitney U test - No trial involvement: median 6.3%, trial involvement: median 5.7%, p-value = 0.0392). Significant key associations were also identified between: prompt surgery and presence of dedicated hip fracture sessions; reduced acute length of stay and both higher number of hip fracture cases per year and more dedicated hip fracture operating lists; Best Practice Tariff attainment and greater number of hip fracture cases per year, more dedicated hip fracture operating lists, presence of a dedicated hip fracture ward and hip fracture trial involvement.

Conclusions:

Exploratory analyses have identified that improved outcomes in hip fracture may be associated with hospital-level service characteristics such as hip fracture research trial involvement, larger hip fracture volumes, and the use of theatre lists dedicated to hip fracture surgery. Further research utilising patient level data is warranted to collaborate these findings.

Take home messages:

- There is little currently available evidence regarding the influence of hospital-level service characteristics on the care of hip fracture patients.
- We have identified a positive relationship between trial participation, hospital size, and the use of dedicated hip fracture theatre lists to important hip fracture outcomes.
- <u>These findings potentially have important implications for hip fracture service delivery, but further research is required to determine their accuracy.</u>

Introduction

Hip fracture is one of the commonest causes of morbidity and mortality in the older population, and the global incidence is expected to rise significantly as a result of shifts in population demographics and co-morbidities [1, 2 3, 4]. Such epidemiological changes will be a challenge to accommodate within the context of financially constrained healthcare systems, particularly those in relatively resource poor nations. Improvement of quality of care through standardisation of processes associated with important healthcare outcomes is one method of providing cost-effective care for all. Across the U.K. national audits have been developed in an attempt to enhance quality of care for hip fracture, with evidence for a reduction in length of stay and mortality seen following the introduction of both the National Hip Fracture Database (NHFD) in England and Wales[5], and also the Scottish Hip Fracture Audit (SHFA) [6].

Previous studies have assessed the impact of U.K. national care standards on hip fracture quality of care [7-9], but there is little known about the effects of hospital-level characteristics on hip fracture care and its relationship to outcomes. Such evidence is required to guide service development and organisation, and to inform the prioritisation of resources in order that the best care can be delivered to the greatest number of patients in the most cost-efficient manner.

The authors hypothesise that the organisation of services and the availability of resources to units managing hip fracture may be an explanatory factor in the observed variation in care quality and patient outcomes. The aim of this study was to identify factors associated with better care quality (indicated by adherence to national care process measures) and patient outcomes by comparing performance of units according to the NHFD quality indicators with their hospital-level characteristics described by the NHFD Facilities Survey.

Materials & Methods

Study design, setting and participants

We undertook a retrospective analysis of prospectively collected, publicly available U.K. national audit data obtained from the National Hip Fracture Database (NHFD) 2018 benchmark summary[10], and the NHFD Facilities Survey 2018[11]. The NHFD is a clinician-led web-based registry with input from 176 hospitals across England, Wales and Northern Ireland. Submission of data for all patients admitted with a hip fracture is mandatory. Financial compensation provided to units for each patient is dependent on submission of patient data to the NHFD and hospital adherence to agreed care standards – the Best Practice Tariff (BPT).

The NHFD benchmark summaries consist of non-identifiable collective information covering assessment, surgery and outcome variables for hip fracture patients from each of the submitting hospitals between 1st January 2018 and 31st December 2018. This included data from 66,578 patients with a hip fracture admitted across the 176 participating units. The facilities survey contains relevant service level characteristics and care process details collected from each individual hospital. Forms are completed by individuals with significant involvement in the care of hip fracture patients and access to necessary information such as consultant orthopaedic surgeons & orthogeriatricians, trauma co-ordinators and hip fracture specialist nurses. This study focuses on information from the facilities audit that relates to identified hospital-level variables.

Data collection

A preformatted proforma was used for data extraction, with data linked between the three sources of information using hospital code. Data extraction was performed independently by two investigators (AH and ADA), with disagreements resolved by a third investigator (LF) where required.

The following hospital-level variables were collected from data available for each of the 176 acute hospitals recorded within the collated audits:

Hospital-level variables included: University hospital or District General Hospital (DGH) status; major trauma centre (MTC) status; number of cases per year; presence of dedicated hip fracture ward; number of inpatient ward beds (denominator for staff per bed calculation); high dependency area (HDU) within the hip fracture ward; number of dedicated hip fracture theatre sessions per week (session defined as approximately 4 hours or half day), and involvement in hip fracture clinical trials (including documented participation in the Warwick Hip Trauma Evaluation [WHiTE] cohort embedded RCTs[12] or similar clinical trials).

The primary outcome measure was adjusted 30-day mortality rate. Secondary outcome measures included: proportion of patients who received surgery on the day of, or day after, admission; length of acute hospital stay; length of overall hospital stay; proportion of patients discharged to original residence within 120 days, and percentage of patients who met the Best Practice Tariff (BPT). The BPT was a composite of: surgery on the day of, or day after, admission; geriatric assessment within 72 hours; preoperative cognitive testing; bone protection assessment; specialist falls assessment; nutritional assessment on admission; post-operative delirium assessment and physiotherapist assessment on the day of, or day after, surgery.

Statistical analysis

Descriptive analyses were performed to define the contained variables for analysis. All missing data were found to be missing completely at random (MCAR), with an overall data completeness rate of 99.5% (likely due to the mandatory nature of data completion). The only included variable with a significant amount of missing data (>5%) was the number of inpatient ward beds (60% completion rate). a random forest-based multivariate imputation by chained equation (MICE) algorithm was utilised for missing value imputation[13].

Univariable analysis was then performed for each of the hospital factors and outcomes listed above. A tobit regression model censoring 0-100 was used for continuous predictors where the outcome variables were provided as percentages of hospital attainment or mortality, otherwise a Siegal non-parametric linear regression was utilised. For categorical predictors, the Mann-Whitney U test was utilised, given that all categorical outcome data were found to be non-parametric on assessment using a Shapiro-Wilk test.

All statistical analyses were performed using R (R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria). Metadata for the statistical analysis is available on request. In all analyses p<0.05 denoted statistical significance.

Ethics

Ethical approval for this study was not required because the data were anonymised at a patient level and obtained from the NHFD website where it remains available to the public.

Results

Results from the descriptive analyses of hospital-level variables are displayed in Table 1. There were 176 hospitals, with a median of 366 hip fracture cases per year. Overall data aggregated from 66,578 patients were included.

Full details of hospital-level variables analysis are displayed in Table 2. Statistically significant results are highlighted in the text below.

30-day mortality

The only identified hospital-level variable associated with 30-day mortality was hip fracture trial involvement (Mann Whitney U test - No trial involvement: median 6.3%, trial involvement: median 5.7%, p-value = 0.0392).

Prompt surgery

The only identified hospital-level variable associated with prompt surgery (i.e. surgery on day of, or day after, admission) was the presence or absence of dedicated hip fracture theatre sessions (HFS) (Mann Whitney U test - HFS present: median 74%, no HFS present: median 71.7%, p-value = 0.0129)

Acute length of stay

Two hospital-level variables had a statistically significant association with acute length of stay (aLOS). Firstly, a higher number of hip fracture cases per year was moderately negatively correlated with aLOS (Estimate -9.431, p = <0.0001). Secondly a greater number of available sessions per week to operate on hip fracture patients (i.e. all available orthopaedic theatre sessions, not just dedicated hip fracture lists, stratified by caseload) showed a weak correlation with increased aLOS (Non-parametric linear regression - Estimate 0.04166, p = <0.0001).

Overall length of stay

Three hospital-level variables had a statistically significant association with overall length of stay (oLOS). Firstly, a higher number of hip fracture cases per year was moderately associated with a shorter oLOS (Estimate -6.499, p <0.0001). A greater number of inpatient ward beds was also weakly associated with a shorter oLOS (Estimate -0.1075 p = <0.0001). Finally, a greater number of non-dedicated hip fracture theatre sessions per week (i.e. all available orthopaedic theatre sessions stratified by caseload) displayed a weak correlation with increased oLOS (Estimate 0.03230 p = <0.0001).

Discharge to original residence within 120 days

There were no hospital-level variables significantly associated with discharge to a patient's original residence within 120 days of admission.

Percentage of patients who met the Best Practice Tariff (BPT)

Five hospital-level variables had a statistically significant association with higher percentage attainment of the BPT. Firstly, a higher number of hip fracture cases per year was weakly correlated with a better chance of BPT completion (Estimate 0.02378, p = 0.0384). Secondly, presence of a dedicated hip fracture ward (HFW) was significantly associated with attainment of the BPT (Mann Whitney U test - median HFW = 62.8%, median no HFW = 58.9%, p-value = 0.0409). The number of inpatient ward beds was also weakly positively correlated with percentage BPT achievement (Estimate 0.52398, p = 0.0362). The presence of dedicated hip fracture theatre sessions (HFS) was also associated with a significantly higher chance of BPT completion (Mann Whitney U test - median

HFS present = 70.3%, median no HFS present = 59.4%, p-value = 0.0016). Finally, higher percentage attainment of the BPT was seen in hospitals involved in hip fracture research trials (Mann Whitney U test - Trial involvement: median 63.8%, No trial involvement: median 59.6%, p-value = 0.0172).

Sensitivity Analyses

The health services in Wales and Northern Ireland do not use the BPT to incentivise performance in their hospitals, and for this reason we performed an additional sensitivity analysis with these hospitals excluded. This confirmed the robustness of the overall findings, with the results of all individual sensitivity analyses contained within Supplementary Table 1.

Discussion

This study demonstrated an association between hospital-level service characteristics and performance with respect to care process measures and patient outcomes. This information provides a valuable insight into the factors associated with improved quality of care and provides evidence for clinicians and service-providers regarding the organisation of current and future hip fracture care. These findings add to evidence from recent studies demonstrating that patient outcomes are associated with patient demographics [14, 15]; adherence to care quality [5,7], and surgical intervention type [16, 17]. It should however be noted that the results are those of exploratory analyses and the interactions seen require further robust investigation utilising patient-level data.

The association between higher hip fracture case volume and improved outcomes (aLOS, oLOS and BPT attainment) is supported by existing evidence that high-volume units are more likely to experience lower mortality rates [18], lower complication rates[19] , and shorter length of hospital admissions. The association between higher hip fracture caseload and improved outcomes may indicate that service centralisation may be beneficial. A possible explanation is that this maximises the efficiency of care processes and resources, as well as the available experience and expertise of care providers. The challenge of ascertaining a true effect has been noted previously due to the methodological weaknesses associated with dichotomisation of continuous variables[20].

There were positive associations between the presence of dedicated hip fracture theatre sessions and both a higher likelihood of timely surgery, and greater BPT attainment. This is consistent with previous literature highlighting the potential benefits for the provision of dedicated hip fracture lists and reduced time to surgery[21].

The reason for a positive correlation between involvement in hip fracture research trials and improved 30-day mortality is unclear, with several potential explanatory factors hypothesised. Firstly, there is a greater likelihood of these units being engaged in quality improvement processes, for example the Hip Fracture Quality Improvement Programme ("HipQIP"), which have been previously shown to be associated with improvements in hip fracture outcomes[22]. Secondly there may be potential for a "Hawthorne effect"[23] regarding observation and subsequent modification of clinical practice associated with trial delivery. This supported by the finding of an association between hip fracture trial involvement and BPT attainment. Another explanatory factor may also be that research-active hospitals are more likely to be larger academic institutions managing a higher volume of patients – again a factor shown in the current study to be associated with better BPT attainment and other quality of care surrogate outcomes such as length of stay. This is consistent with a previous study by Metcalfe et al. that identified an association between hip fracture research participation, hospital size, hip fracture volume and MTC status[24]. There is a possibility that larger hospital size and participation in hip fracture trials may help drive BPT attainment that has been previously independently associated with improved mortality at a patient level[8], although we did not see a direct association between hospital size and mortality in this study. We also did not identify any association between MTC status and hip fracture outcome.

Strengths of the study include its large size, excellent data quality and its national sample representative of hip fracture care delivery within a developed healthcare system. Use of continuous rather than dichotomised methods for analysis allowed for a better representation of true effect from the included variables.

The main limitation to the study is that only univariable analysis was possible due to the use of aggregated data. The inability to include patient level information in the current study means that some, or all, of the identified association may be explained by factors not explored within this analysis. It is important to therefore highlight that the results are exploratory in nature and should be utilised to serve as basis for further confirmatory research based on the associations identified. Future use of individual patient data utilising a multilevel model taking into account hierarchical data will likely provide a more accurate representation of the influence of hospital-level factors to guide service delivery. It is however important to note that the complexity of factors linking hip fracture variables and outcomes is significant, and it is likely impossible to fully control for all variables within any specific analysis.

This study provides incentive and support for further studies focusing on similar service-level variables, such as staffing volume and composition for key individuals such as nursing staff, orthogeriatricians and allied health professionals. These have previously been associated with improved patient outcomes in other settings [24,25], as well as hip fracture care [25-27,28]. Future cluster randomised controlled trials of identified factors, such as the presence of dedicated hip fracture lists, would significantly strengthen the evidence for the importance of hospital level variables on healthcare outcomes.

Conclusions

Improved outcomes in hip fracture were associated with hip fracture research trial involvement, larger hip fracture case volume, and the availability of theatre lists dedicated to hip fracture surgery. These findings suggest that there may be a potential benefit to the centralisation of hip fracture services in order to increase quality of care, efficiency, and patient outcomes. The results should however be interpretated as explanatory due to the nature of included data and analysis, with further patient-level data required to confirm these findings before definitive suggestions regarding changes to service provision can be made.

References

1. Richmond J, Aharonoff GB, Zuckerman JD, Koval KJ. Mortality risk after hip fracture. J Orthop Trauma. 2003;17(1):53-6.
2. Dyer SM, Crotty M, Fairhall N, Magaziner J, Beaupre LA, Cameron ID, et al. A critical review of the long-term disability outcomes following hip fracture. BMC Geriatr. 2016;16:158.
3. Holt G, Smith R, Duncan K, Hutchison JD, Reid D. Changes in population demographics and the future incidence of hip fracture. Injury. 2009;40(7):722-6.
4. Dhanwal DK, Dennison EM, Harvey NC, Cooper C. Epidemiology of hip fracture: Worldwide geographic variation. Indian J Orthop. 2011;45(1):15-22.
5. Metcalfe D, Zogg CK, Judge A, Perry DC, Gabbe B, Willett K, et al. Pay for performance and hip fracture outcomes: an interrupted time series and difference-in-differences analysis in England and Scotland. Bone Joint J. 2019;101-B(8):1015-23.
6. Ferguson KB, Halai M, Winter A, Elswood T, Smith R, Hutchison JD, et al. National audits of hip fractures: Are yearly audits required? Injury. 2016;47(2):439-43.
7. Farrow L, Hall A, Wood AD, Smith R, James K, Holt G, et al. Quality of Care in Hip Fracture Patients: The Relationship Between Adherence to National Standards and Improved Outcomes. J Bone Joint Surg Am. 2018;100(9):751-7.
8. Oakley B, Nightingale J, Moran CG, Moppett IK. Does achieving the best practice tariff improve outcomes in hip fracture patients? An observational cohort study. BMJ Open. 2017;7(2):e014190.
9. Neuburger J, Currie C, Wakeman R, Tsang C, Plant F, De Stavola B, et al. The impact of a national clinician-led audit initiative on care and mortality after hip fracture in England: an external evaluation using time trends in non-audit data. Med Care. 2015;53(8):686-91.

10. NHFD. Benchmark Summary 2018 [Available from: https://www.nhfd.co.uk/20/nhfdcharts.nsf/fmbenchmarks?ReadForm&report=outcomes&year=2018.
11. NHFD. Facilities Audit 2018 [Available from: https://www.nhfd.co.uk/2018report.
12. Griffin XL, Achten J, Parsons N, Boardman F, Griffiths F, Costa ML. The Warwick Hip Trauma Evaluation - an abridged protocol for the WHiTE Study: A multiple embedded randomised controlled trial cohort study. Bone Joint Res. 2012;1(11):310-4.
13. Shah AD, Bartlett JW, Carpenter J, Nicholas O, Hemingway H. Comparison of random forest and parametric imputation models for imputing missing data using MICE: a CALIBER study. Am J Epidemiol. 2014;179(6):764-74.
14. Smith T, Pelpola K, Ball M, Ong A, Myint PK. Pre-operative indicators for mortality following hip fracture surgery: a systematic review and meta-analysis. Age Ageing. 2014;43(4):464-71.
15. Tsang C, Boulton C, Burgon V, Johansen A, Wakeman R, Cromwell DA. Predicting 30-day mortality after hip fracture surgery: Evaluation of the National Hip Fracture Database case-mix adjustment model. Bone Joint Res. 2017;6(9):550-6.
16. Investigators H, Bhandari M, Einhorn TA, Guyatt G, Schemitsch EH, Zura RD, et al. Total Hip Arthroplasty or Hemiarthroplasty for Hip Fracture. N Engl J Med. 2019;381(23):2199-208.
17. Whitehouse MR, Berstock JR, Kelly MB, Gregson CL, Judge A, Sayers A, et al. Higher 30-day mortality associated with the use of intramedullary nails compared with sliding hip screws for the treatment of trochanteric hip fractures: a prospective national registry study. Bone Joint J. 2019;101-B(1):83-91.
18. Yoo S, Jang EJ, Jo J, Jo JG, Nam S, Kim H, et al. The association between hospital case volume and in-hospital and one-year mortality after hip fracture surgery. Bone Joint J. 2020;102-B(10):1384-91.
19. Wiegers EJA, Sewalt CA, Venema E, Schep NWL, Verhaar JAN, Lingsma HF, et al. The volume-outcome relationship for hip fractures: a systematic review and meta-analysis of 2,023,469 patients. Acta Orthop. 2019;90(1):26-32.
20. Royston P, Altman DG, Sauerbrei W. Dichotomizing continuous predictors in multiple regression: a bad idea. Stat Med. 2006;25(1):127-41.
21. Basheer S, Wood D, Shepherd K, McGregor-Riley J. Dedicated Hip Fracture Lists: Improving the Service Received by Orthopaedic Trauma Patients2013. Available from: https://publishing.rcseng.ac.uk/doi/pdf/10.1308/147363513X13500508919934.
22. FFFAP. NHFD 2019 Annual Report2019 21/02/2021. Available from: https://www.nhfd.co.uk/files/2019ReportFiles/NHFD_2019_Annual_Report_v101.pdf.
23. McCarney R, Warner J, Iliffe S, van Haselen R, Griffin M, Fisher P. The Hawthorne Effect: a randomised, controlled trial. BMC Med Res Methodol. 2007;7:30.
24. Metcalfe D, Costa ML, Parsons NR, Achten J, Masters J, Png ME, Lamb SE, Griffin XL. Validation of a prospective cohort study of older adults with hip fractures. The bone & joint journal. 2019 Jun;101(6):708-14.
25. Myint PK, M OB, Loke YK, S DM, Price GM, Hale R, et al. Important factors in predicting mortality outcome from stroke: findings from the Anglia Stroke Clinical Network Evaluation Study. Age Ageing. 2017;46(1):83-90.
26. Rapp K, Becker C, Todd C, Rothenbacher D, Schulz C, Konig HH, et al. The Association Between Orthogeriatric Co-Management and Mortality Following Hip Fracture. Dtsch Arztebl Int. 2020;117(4):53-9.
27. Della Rocca GJ, Moylan KC, Crist BD, Volgas DA, Stannard JP, Mehr DR. Comanagement of geriatric patients with hip fractures: a retrospective, controlled, cohort study. Geriatr Orthop Surg Rehabil. 2013;4(1):10-5.
28. Schilling P, Goulet JA, Dougherty PJ. Do higher hospital-wide nurse staffing levels reduce in-hospital mortality in elderly patients with hip fractures: a pilot study. Clin Orthop Relat Res. 2011;469(10):2932-40.

Supplementary Table 1. Results of hospital level variable sensitivity analyses with hospitals from Wales & Northern Ireland excluded.

	Outcome								
Variable	***30-day mortality***			***% Prompt surgery***			***Acute length of stay***		
	Mann Whitney U test								
	Median (%)	**W**	***p***	**Median (%)**	**W**	***p***	**Median (days)**	**W**	***p***
By hospital type:									
District General Hospital	5.9	2885	0.482	74.5	3559	0.1018	14.7	2766	0.2639
University Hospital	6.2			71.9			16.0		
By MTC:									
MTC	6.1	1473	0.9496	73.9	1770	0.1178	17.1	1257	0.3061
No MTC	6.0			71.7			14.9		
Presence of dedicated hip fracture ward:									
Hip fracture ward	6.1	2781	0.7019	73.6	2942	0.8462	15.0	31168	0.3144
No hip fracture ward	5.9			72.1			15.4		
Presence of HDU area:									
HDU	5.6	1440	0.8385	70.6	1550	0.4405	15.3	1526	0.5172
No HDU	6.1			73.3			15.2		
Presence vs absence of any dedicated hip fracture sessions:									
Median hip fracture sessions present	5.7	3166	0.6091	**74.5**	**2361**	**0.0207**	15.4	3254	0.412
Median no hip fracture sessions present	6.2			**72.0**			14.7		
Hip fracture trial involvement:									
Trial involvement	**5.6**	**3419**	**0.0345**	72.5	2663	0.5317	15.4	3171	0.2252
No trial involvement	**6.3**			73.2			14.7		

	Tobit regression model censoring 0-100								**Siegal non-parametric linear regression**			
	Estimate	**SE**	**Z value**	***p***	**Estimate**	**SE**	**Z value**	***p***	**Estimate**	**MAD**	**V value**	***p***
Vs. cases per year	-0.0005125	0.0009628	-0.532	0.595	-0.003873	0.006290	-0.616	0.538	**-12.63**	**16.49**	**2560**	**<0.0001**
Number of inpatient ward beds	0.005276	0.19435	0.271	0.786	**0.31297**	**0.12470**	**2.51**	**0.0121**	**-0.1136**	**0.3992**	**2802**	**0.0108**
Number of theatre sessions per week by caseload	-0.007901	0.083016	-0.095	0.924	0.52405	0.54159	0.968	0.333	**0.05291**	**0.08934**	**19386**	**<0.0001**

Supplementary Table 1. Continued.

	Outcome								
Variable	***Overall length of stay***			***Discharge to original residence 120 days***			***% Met best practice tariff***		
	Mann Whitney U test								
	Median (days)	**W**	***p***	**Median (%)**	**W**	***p***	**Median (%)**	**W**	***p***
By hospital type:									
District General Hospital	**18.1**	**2486**	**0.0368**	72.2	3412	0.2603	63.4	3284	0.4959
University Hospital	**19.9**			69.9			62.3		
By MTC:									
MTC	20.7	1184	0.1646	68.6	1768	0.1196	62.8	1613	0.4409
No MTC	18.8			71.7			62.9		
Model of Orthogeriatric care:									
Group 1	18.0	1795	0.0873	70.60	2049	0.5811	63.4	2182	0.96
Group 2	19.5			72.05			62.0		
Presence of dedicated hip fracture ward:									
Hip fracture ward	18.8	3089	0.4702	71.9	2472	0.136	62.9	2748	0.6163
No hip fracture ward	19.4			70.1			61.7		
Presence of HDU area:									
HDU	19.3	1254	0.4513	70.1	1566	0.3946	61.6	1448	0.8084
No HDU	18.7			71.6			63.2		
Presence vs absence of any dedicated hip fracture sessions:									
Median hip fracture sessions present	18.0	3404	0.1779	71.1	3135	0.6862	**71.1**	**2120**	**0.0016**
Median no hip fracture sessions present	19.1			70.3			**60.5**		
Hip fracture trial involvement:									
Trial involvement	19.2	2629	0.4551	71.1	2733	0.7102	**65.3**	**2238**	**0.0303**
No trial involvement	18.7			70.9			**61.7**		

Variable	***Overall length of stay***				***Discharge to original residence 120 days***				***% Met best practice tariff***			
	Siegal non-parametric linear regression				***Tobit regression model censoring 0-100***							
	Estimate	**MAD**	**V value**	***p***	**Estimate**	**SE**	**Z value**	***p***	**Estimate**	**SE**	**Z value**	***p***
Vs. cases per year	**-6.377**	**12.402**	**3095**	**<0.0001**	-0.000225	0.0052169	-0.043	0.966	**0.025497**	**0.009056**	**2.816**	**0.0049**
Number of inpatient ward beds	**-0.1620**	**0.3624**	**2930**	**0.0004**	0.03043	0.10521	0.289	0.772	**0.5022**	**0.1828**	**2.748**	**0.006**
Number of theatre sessions per week by caseload	**0.0422**	**0.0523**	**9853**	**<0.0001**	0.35848	0.44860	0.799	0.424	**-2.00721**	**0.78415**	**-2.56**	**0.0105**

***p* = p value; MAD = Median absolute deviation; MTC = Major Trauma Centre, HDU = High Dependency Unit. For Model of Orthogeriatric care: Group 1 = Shared geriatric and orthopaedic care, Group 2 = Orthopaedic care with routine geriatric review.**

Table 1. Descriptive analysis of hospital level variables (176 hospitals including 66,578 patients)

Hospital characteristics (N=176)	**No. (%)**
University Hospitals	68 (38.6)
District General Hospital	108 (61.4)
Major Trauma Centres	21 (11.9)
Dedicated hip fracture ward	109/173 (63.0)
HDU setting on ward	21 (11.9)
Involved in hip fracture trials	56 (31.8)
Other characteristics	
Cases per year	**Median (range) (SD)**
Theatre sessions per week	366 (46-937) (159)
Theatre sessions per week by cases per week	14 (2-21) (4)
No dedicated hip fracture sessions per week (108/173), range excluding cases with 0 sessions	3 (range 1-16) (2)
Hip fracture sessions per week by cases per week	7 (0-28)
Inpatient ward beds	1.0 (0.1-7.9) (1.1)
	28 (8-56) (7)

Table 2. Results of hospital level variable analyses.

Variable	Outcome: *30-day mortality*			*% Prompt surgery*			*Acute length of stay*		
	Mann Whitney U test								
	Median (%)	**W**	***p***	**Median (%)**	**W**	***p***	**Median (days)**	**W**	***p***
By hospital type:									
District General Hospital	6.1	3427.5	0.4583	73.3	4073	0.2236	14.7	3199.5	0.1515
University Hospital	6.3			71.5			16.7		
By MTC:									
MTC	6.1	1655	0.9019	71.7	1864.5	0.2804	17.1	1436	0.3833
No MTC	6.1			73.1			15.2		
Presence of dedicated hip fracture ward:									
Hip fracture ward	6.2	3426	0.4929	72.1	3288.5	0.2694	14.7	4176.5	0.11
No hip fracture ward	5.9			72.4			15.8		
Presence of HDU area:									
HDU	5.7	1712.5	0.9358	72.1	1823.5	0.7805	15.2	1948	0.2567
No HDU	6.1			72.3			15.4		
Presence vs absence of any dedicated hip fracture sessions:									
Median hip fracture sessions present	5.8	3708	0.7591	**74.0**	**2796**	**0.0129**	15.1	3800.5	0.5551
Median no hip fracture sessions present	6.3			**71.7**			15.4		
Hip fracture trial involvement:									
Trial involvement	**5.7**	**4009.5**	**0.0392**	72.1	3100.5	0.4107	14.9	3762.5	0.2016
No trial involvement	**6.3**			72.4			15.5		

Variable	*Tobit regression model censoring 0-100*: 30-day mortality				% Prompt surgery				**Siegal non-parametric linear regression**: Acute length of stay			
	Estimate	**SE**	**Z value**	***p***	**Estimate**	**SE**	**Z value**	***p***	**Estimate**	**MAD**	**V value**	***p***
Vs. cases per year	2.426e-05	9.422e-04	0.026	0.979	-0.009067	0.006733	-1.347	0.178	**-9.431**	**18.158**	**18.158**	**<0.0001**
Number of inpatient ward beds	-0.01379	0.02049	-0.673	0.501	0.16944	0.11732	1.444	0.149	0.00	0.4901	3958	0.96
Number of theatre sessions per week by caseload	-0.05547	0.07397	-0.75	0.453	0.62034	0.61565	1.008	0.314	**0.04166**	**0.08353**	**11823**	**<0.0001**

Table 2. Continued.

Variable	Overall length of stay			Discharge to original residence 120 days			% Met best practice tariff		
	Mann Whitney U test								
	Median (days)	**W**	***p***	**Median (%)**	**W**	***p***	**Median (%)**	**W**	***p***
By hospital type:									
District General Hospital	18.8	3279.5	0.2336	72.5	4105.5	0.1883	61.6	3596	0.8185
University Hospital	20.1			69.95			61.8		
By MTC:									
MTC	20.7	1481.5	0.5066	68.6	2012	0.0797	62.8	1629.5	0.9945
No MTC	19.2			72.4			61.5		
Model of Orthogeriatric care:									
Group 1	18.7	2117.5	0.1009	70.1	2046.5	0.0536	63.3	2669	0.5445
Group 2	20.3			73.2			61.3		
Presence of dedicated hip fracture ward:									
Hip fracture ward	18.8	4239	0.0739	72.6	3292.5	0.2747	**62.8**	**2980**	**0.0409**
No hip fracture ward	20.4			71.0			**58.9**		
Presence of HDU area:									
HDU	19.7	1635.5	0.7953	72.1	1820	0.5745	61.6	1604	0.6889
No HDU	19.1			70.6			61.6		
Presence vs absence of any dedicated hip fracture sessions:									
Median hip fracture sessions present	18.7	4112	0.1223	71.1	3791	0.5748	**70.3**	**2576.5**	**0.0016**
Median no hip fracture sessions present	19.8			71.9			**59.4**		
Hip fracture trial involvement:									
Trial involvement	19.5	3359	0.9987	71.1	3390	0.9253	**63.8**	**2609.5**	**0.0172**
No trial involvement	19.2			72.1			**59.6**		

Variable	Siegal non-parametric linear regression				Tobit regression model censoring 0-100							
	Estimate	**MAD**	**V value**	***p***	**Estimate**	**SE**	**Z value**	***p***	**Estimate**	**SE**	**Z value**	***p***
Vs. cases per year	**-6.499**	**10.094**	**3507**	**<0.0001**	0.0006997	0.0047832	-0.146	0.884	**0.02378**	**0.01148**	**2.07**	**0.0384**
Number of inpatient ward beds	**-0.1075**	**0.2526**	**2648**	**0.0001**	0.05064	0.10408	0.487	0.627	**0.52398**	**0.25014**	**0.25014**	**0.0362**
Number of theatre sessions per week by caseload	**0.03230**	**0.05149**	**11930**	**<0.0001**	0.21694	0.37578	0.577	0.564	-1.25591	0.90875	-1.382	0.167

p = p value; MAD = Median absolute deviation; MTC = Major Trauma Centre, HDU = High Dependency Unit. For Model of Orthogeriatric care: Group 1 = Shared geriatric and orthopaedic care, Group 2 = Orthopaedic care with routine geriatric review.