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Hospital Case Volume and Outcomes for Proximal Femoral Fractures: a Statewide Observational Study.

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Key words

Minimum volume thresholds; volume-outcome; hip fracture

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Abstract

Objective: To explore whether older adults with isolated hip fractures benefit from treatment in high-volume hospitals.

Design: Population-based observational study.

Setting: All acute hospitals in California, USA.

Participants: All individuals aged ≥65 that underwent an operation for an isolated hip fracture in California between 2007 and 2011. Patients transferred between hospitals were excluded.

Primary and secondary outcomes: Quality indicators (time to surgery) and patient outcomes (length of stay, in-hospital mortality, unplanned 30-day re-admission, and selected complications).

Results: 91,401 individuals satisfied the inclusion criteria. Time to operation and length of stay were significantly prolonged in low volume hospitals, by 1.96 (95% CI 1.20-2.73) and 0.70 (0.38-1.03) days respectively. However, there were no differences in clinical outcomes, including in-hospital mortality, 30-day re-admission, and rates of pneumonia, pressure ulcers, and venous thromboembolism.

Conclusion: These data suggest that hip fracture care may be less efficient in low volume hospitals but that clinical outcomes are equivalent to those in high volume centres.

Strengths and limitations

- The California State Inpatient Database captures 98% of patient admissions to acute hospitals in a state of over X million people.
- Unique patient and hospital identifiers permitted calculation of annual case volumes and tracking patient readmissions to any hospital in California.
- This methodological approach adjusted for important patient- and hospital-level characteristics but may be limited by residual confounding.

Funding

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Competing interests

No competing interests.

Introduction

There are approximately 250,000 hip fractures in the United States[1] every year, which are a major cause of mortality and morbidity. High provider case volumes have been associated with improved outcomes across a range of surgical procedures, including major arterial vascular surgery[2], oesophageal resection[3], and elective arthroplasty[4,5]. A small number of studies have explored the effect of hospital volume on hip fracture outcomes[6-11]. However, these reports reached inconsistent conclusions, with only two identifying a relationship between hospital volume and outcomes[7,10]. These studies predominantly used cross-sectional datasets that could not measure longitudinal outcomes such as re-admission to hospital and complications following discharge[6,8,10]. They also included cases from over fifteen years ago[7] that are unlikely to reflect modern hip fracture management. Contemporary hip fracture treatment emphasizes the use of standardized clinical pathways[12], formal geriatric assessment[13], and early operation to expedite mobility[14]. It is possible that the increasing standardization of hip fracture management will have influenced any relationship between clinical outcomes and provider volume.

A recent systematic review called for more studies aimed at characterizing volume-outcome relationships for specific orthopaedic patient populations[15]. This is necessary to determine the optimal setting for hip fracture patients and to inform both pre-hospital triage and inter-hospital referral pathways.

The aim of this study was to explore associations between case volume and outcomes using a comprehensive population database.

Methods

Data source

Hospital discharge records were analyzed from the California State Inpatient Database (SID) 2007-2011. The SID is managed by the Healthcare Cost and Utilization Project (HCUP) which is an initiative of the US Agency for Healthcare Research and Quality (AHRQ) intended both for administrative and research purposes. It includes all inpatient discharge records from 98% of hospitals in California[16], regardless of payment source. Unique patient identifiers allow individuals to be tracked between admissions, so permitting longitudinal analysis of patient-level data. The SID was linked to the American Hospital Association (AHA) Annual Survey Database so that specific hospital characteristics (e.g. trauma centre status) could be included within the analysis.

Study population

Patients with a primary or secondary International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) diagnosis code indicating "fracture of neck of femur" (820.0-820.9) were extracted from the SID. Patients were excluded if they were aged <65 years, treated non-operatively, subject to an inter-hospital transfer, or had any other injury with an Abbreviated Injury Scale (AIS) severity score ≥2. Age 65 was chosen to exclude higher energy hip fractures in younger patients and because individuals aged ≥65 in the US are universally insured through Medicare. Patients transferred between hospitals were excluded to minimize selection bias.

Patient and hospital characteristics

Extracted patient characteristics included age, sex, race (white, black, Hispanic, other), payment source (publicly funded, private insurance, self-pay), and weekend admission.

Abbreviated Injury Scale and Charlson co-morbidity indices were generated using the ICDPIC and CHARLSON modules respectively in Stata Statistical Software Release 13.0 (College Station, Texas, USA). The Charlson co-morbidity index (CCI) is a weighted score derived from 22 co-morbid diagnoses. It is the most widely used co-morbidity score for analyzing administrative datasets[17] and has been shown to predict both resource utilization[18] and mortality[19] in hip fracture populations.

Hospital characteristics included trauma centre level (1-4, with level 1 representing large regional trauma centres), teaching status (defined as hosting a physician training programme accredited by the Accreditation Council for Graduate Medical Education [ACGME]), and hospital bed size (categorized as <200 and ≥200 beds).

Unique identifiers within the SID were used to determine the annual hip fracture case volume of each hospital. Visual inspection of a histogram (number of hip fracture patients versus the annual volume at each treating hospital) revealed four distinct groups (Figure 1). The four volume groups were defined as: low <20, intermediate-low 20-99, intermediate-high 100-215, and high >215 cases per year. Although data from all categories are reported, the principal comparison in this paper was between high and low volume hospitals.

Outcome measures

Outcome measures included length of stay, in-hospital mortality, unplanned re-admission, and selected complications experienced as an inpatient or within 30 days post-discharge from the hospital. Complications were identified by ICD-9-CM codes as venous thromboemboli (deep vein thrombosis 453.4, pulmonary embolus 415.1,

pneumonias (480-488), and decubitus ulcers (707.0). These complications were also considered together as a single composite outcome. Only patients discharged alive from the hospital were eligible for calculating length of stay and 30-day re-admission. Re-admissions and sequelae were captured even if the patient presented to a different (non-index) hospital in the state of California rather than the institution that treated their hip fracture.

Sensitivity analysis

As comparatively few patients (and associated adverse events) were anticipated in the low volume category, a sensitivity analysis was planned with low and intermediate-low volume categories combined before comparison with the two higher volume groups.

Statistical analysis

Outcome variables were compared between the volume quartiles using Chi-square tests for categorical variables and Kruskall-Wallis one-way analysis of variance for non-normally distributed continuous variables. Multivariable logistic regression models were used to examine the risk-adjusted associations of case volume with mortality, unplanned 30-day re-admission, and post-operative complications. Co-variates included in regression models were age, sex, race, payment source, weighted CCI (as a continuous co-variate), discharge destination, hospital bed size, teaching status, and trauma centre level. All models accounted for clustering of patients within hospitals and used robust standard errors.

Length of stay (LOS) presented as right-skewed data and so risk-adjusted associations were explored using generalized linear regression with a gamma distribution[20] and link

log followed by post-estimation of average marginal effects to attain predicted mean differences in LOS. The threshold for statistical significance was set at two-sided $p < 0.05$. Statistical analyses were performed using Stata 13.0. The Partners Human Research Committee approved the study protocol (IRB 2014P002072/BWH).

Results

Patient and hospital characteristics

There were 91,401 patients in the final cohort, demographic and admission characteristics for which are shown in Table 1. The mean age was 81.7 (SD 8.3) years. The patients were predominantly female (71.7%), white (81.0%), publicly insured (91.1%), admitted during the working week (72.6%), and had a CCI <2 (68.7%). A greater proportion of non-white and male patients were treated in lower volume hospitals. Patients were more commonly treated at a high volume hospital if presenting during the weekend (27.4% vs 21.4%, $p < 0.001$).

Within California, there were 257 individual hospitals that treated hip fractures, characteristics of which are described in Table 2. They were predominantly teaching institutions (77.0%) without trauma centre designation (73.2%) and located in a non-rural setting (87.9%). The mean annual case volume was 79.1 (SD 72.6). However, this varied significantly between the categories: low 5.2 (SD 6.0), intermediate-low 59.0 (SD 22.6), intermediate-high 150.0 (SD 34.5), and high volume 276.0 (SD 37.5) cases per year ($p < 0.001$). A higher proportion of low volume hospitals were rurally situated (23.5% vs 0.0%, $p < 0.001$) and maintained an accredited residency program (79.4% vs 73.3%, $p < 0.001$) but a lower proportion were designated as a trauma centre (26.8% vs

33.3%, p < 0.001). Low volume hospitals were also smaller in size, ranging from a mean of 109.3 beds in the low volume to 348.8 in the high volume category (p < 0.001).

Clinical outcomes

The unadjusted outcomes are summarized in Table 3 and results of the multivariable regression analyses in Table 4.

Time to operation

The overall median time to the operating theatre was 1.0 days (IQR 0.0 to 2.00). In the unadjusted analysis, low volume hospitals had a longer time to theatre (median 1, 90th percentile 3 days) than high volume hospitals (median 1, 90th percentile 2 days) (p < 0.001). Within a generalized linear regression model, adjusted surgical delay was inversely associated with hospital volume (p < 0.001). This was a stepwise association with a higher predicted mean difference observed in each successive volume category relative to high volume hospitals: intermediate-high 0.34 (95% CI 0.05 to 0.62), intermediate-low 1.14 (0.80 to 1.48), and low 1.96 (1.20 to 2.73). Patients in the lowest volume hospitals therefore reached the operating theatre almost two days later than those in the highest volume category (p < 0.001).

Length of stay

Median LOS was 5.0 (IQR 4.0 to 6.0) days but this was inversely associated with case volume in both unadjusted and adjusted analyses. In the multivariable regression model, there was no significant difference between the two highest volume categories. However, LOS in the intermediate-low volume and low volume groups were 0.32 and 0.70 days longer respectively. A higher proportion of patients were discharged to

another care facility from high volume hospitals than from low volume hospitals (86.9% vs 79.2%, p < 0.001).

In-hospital mortality

There were 1,663 in-hospital deaths in the cohort, with an overall mortality of 1.8%. There were no significant differences between volume categories in terms of in-hospital mortality, either in the unadjusted (p = 0.585) or adjusted (p = 0.380) analyses. The sensitivity analysis (high volume versus combined low and intermediate-low volume hospitals) also did not detect any difference between the combined low volume and high volume categories (p = 0.964).

30-day unplanned re-admissions

A total of 9,888 (11.0%) patients required unplanned re-admission to hospital within 30 days of discharge. Rates of re-admission varied between the groups with the highest rate observed in the low volume category (12.6%, p = 0.042). In the multivariable analysis, there was no consistent association between case volume and likelihood of re-admission (OR 1.06, 95% CI 0.65 to 1.73). This finding was confirmed by the sensitivity analysis with combined low volume categories (OR 0.88, 0.74 to 1.05).

Hip fracture sequelae

Major hip fracture sequelae (venous thromboembolism, decubitus ulcers, and pneumonia) were reported in 9,513 cases (10.4%). They occurred more commonly in the lowest volume category (11.0 vs 9.7%, p < 0.001). However, this difference was not significant in the multivariable regression analysis (Table 4).

There were 2,194 patients with venous thromboembolism (2.4%), 6,237 with decubitus ulcers (6.8%), and 1,866 with pneumonia (2.0%). In the unadjusted analyses, decubitus ulcers and pneumonia occurred more commonly in low volume hospitals while VTE occurred in high volume hospitals (all $p < 0.001$). However, there were no differences in either the primary adjusted (Table 4) or sensitivity analyses.

Discussion

This study found evidence of less efficient hip fracture treatment (delayed operation and prolonged LOS) in low volume hospitals. However, it did not identify any relationship between volume and clinical outcomes for patients with hip fractures. This is the first study to examine the relationship between hospital case volume and hip fracture outcomes using a contemporary population dataset. Importantly, post-discharge complications could be identified if they required admission to any hospital in the state. Previous studies are dated or used cross-sectional databases that could not facilitate longitudinal follow-up of patients between institutions[6-11].

In this study, the mean hip fracture case volume was 79.1 per year; with a relatively high number of low volume (<20 per year) hospitals. Although the mean annual case volume in California was higher than previously described across the US[7,21], hip fracture cases may be more concentrated in other settings. For example, in the United Kingdom, only six hospitals reported annual case volumes <100 in 2014[22].

Although two previous studies have reported an inverse relationship between hospital volume and hip fracture mortality[7,10], no such finding emerged from this comprehensive population dataset. This also conflicts with reports from other distinct surgical

populations[2-5]. One possibility is that hip fractures are commonly encountered during orthopaedic training[23] and so surgeons should therefore be familiar with the needs of this patient group, even in low volume centres. This might explain why hip fractures do not exhibit the volume-outcome relationship that has been identified for more specialized populations, e.g. those undergoing revision arthroplasty surgery[4,5]. Hip fracture treatment is also increasingly driven by protocols and pathways, which might reduce variation between hospitals[12,24].

There was however evidence of higher quality care in high volume centres. These include reduced delay to the operating theatre and length of stay. One possible explanation for this finding is that staff expertise and clinical pathways improve with the experience that results from treating high numbers of similar patients. For example, pathways and processes might have been more developed at higher volume centres. It is important that, although length of stay was shorter at high volume centres, patients were more likely to be discharged to another healthcare facility than their own home. This suggests that relationships with other institutions (such as skilled nursing facilities) may contribute to achieving a shorter length of stay. It is also a reminder that discharge from hospital does not necessarily represent the end of each patient journey.

An alternative explanation is proposed by the "selective referrals" hypothesis, which claims that high quality hospitals are referred a greater number of patients[9]. This reverses the presumed direction of causation between volume and outcome. In this study, we controlled for some fixed hospital characteristics (e.g. trauma centre status) but unknown hospital-level founding factors might have persisted. However, patients

transferred between institutions were excluded to minimize the "selective referrals" effect.

Although prolonged operation time has been associated with hip fracture sequelae (venous thromboembolism, pneumonia, and decubitus ulcers)[25], these were not over-represented in the lower volume centres.

This study is not without limitations. As the SID is a retrospective dataset, unknown confounding factors might have been omitted from our multivariable regression models. In particular, it was not possible to determine the role of individual surgeon case volume. Previous studies have suggested that surgeon volume may be even more important than hospital volume on patient outcomes. In one series of 173,508 elderly patients undergoing hip hemiarthroplasty for fracture, surgeons in the lowest volume quartile had an 18% increased mortality compared with those in the highest[10]. It also is known that low volume surgeons cluster in low volume hospitals across a range of surgical procedures[26,27]. However, we accounted for clustering of fixed hospital-level characteristics in the multivariable regression analysis, which should have controlled for such differences. Although we found no hospital-level effect, it is still possible that low volume surgeons could have worse mortality outcomes, even in the absence of hospital-level differences.

Conclusion

In light of these findings, there is no patient safety imperative to discourage low volume hospitals from treating patients with hip fractures. This is particularly true in settings with higher overall hospital case volumes. However, hip fracture care in low volume

hospitals may be less efficient which could have healthcare resource implications. Further work should determine whether this pattern is observed outside the US and to quantify the excess costs of treating hip fracture patients in lower volume hospitals.

Author contributions

DM conceived the study idea, undertook the statistical analysis, and drafted the manuscript. OO, BG, CZ, MH, DP, AS and MC contributed to the study design, interpretation of findings, and made critical revisions to the manuscript.

Data sharing agreement

The California State Inpatient Database is available on application to the Healthcare Cost and Utilization Project (HCUP), https://www.hcup-us.ahrq.gov.

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Table 1: Demographic characteristics of the final hip fracture cohort						
	High volume	**Intermediate-high volume**	**Intermediate-low volume**	**Low volume**	**Total cohort**	**P**
Patients	16,992	47,513	26,079	817	91,401	
Age	82.1 (SD 8.2)	81.9 (SD 8.2)	81.2 (SD 8.4)	78.9 (SD 8.8)	81.7 (SD 8.3)	< 0.001*
Sex						
Male	4,764 (28.1%)	13,251 (28.0%)	7,480 (28.9%)	255 (32.6%)	25,750 (28.3%)	
Female	12,172 (71.9%)	34,092 (72.0%)	18,415 (71.1%)	527 (67.4%)	65,206 (71.7%)	0.003**
Race						
White	14,784 (88.5%)	38,284 (82.2%)	18,674 (74.6%)	426 (58.6%)	72,168 (81.0%)	
Black	209 (1.3%)	862 (1.9%)	771 (3.1%)	23 (3.2%)	1,865 (2.1%)	
Hispanic	971 (5.8%)	4,452 (9.6%)	2,692 (11.8%)	245 (33.7%)	8,630 (9.7%)	
Other	736 (4.4%)	2,997 (6.4%)	2,626 (10.5%)	33 (4.5%)	6,392 (7.2%)	< 0.001**
Payment source						
Self-pay	116 (0.7%)	210 (0.4%)	253 (0.6%)	5 (0.6%)	484 (0.5%)	
Private	1,192 (7.0%)	3,678 (7.7%)	1,825 (7.0%)	56 (6.9%)	6,761 (7.4%)	
Public	15,583 (91.7%)	43,168 (90.9%)	23,730 (91.0%)	731 (89.5%)	83,212 (91.1%)	
Other	101 (0.6%)	451 (1.0%)	361 (1.4%)	25 (3.1%)	938 (1.0%)	< 0.001**
Weekend admission						
Yes	4,654 (27.4%)	13,158 (27.7%)	7,039 (27.0%)	175 (21.4%)	25,026 (27.4%)	
No	12,338 (72.6%)	34,355 (72.3%)	19,040 (73.0%)	642 (78.6%)	66,375 (72.6%)	< 0.001**
Charlson index						
<2	11,767 (69.3%)	32,455 (68.3%)	18,007 (69.1%)	589 (72.1%)	62,818 (68.7%)	
≥2	5,225 (30.8%)	15,058 (31.7%)	8,072 (31.0%)	228 (27.9%)	28,583 (31.3%)	0.009**

*Kruskall-Wallis one-way analysis of variance; **Chi squared test

Table 2: Characteristics of hospitals treating patients in each volume category

	High volume	Intermediate-high volume	Intermediate-low volume	Low volume	Total cohort	P
N	15	82	126	34	257	
Mean annual volume	276 (SD 37.5)	150 (SD 34.5)	59 (SD 22.6)	5.2 (SD 6.0)	79.1 (SD 72.6)	< 0.001*
Hospital bed size	348.8 (SD 142.7)	229.3 (SD 145.8)	137.9 (SD 100.3)	109.3 (SD 117.6)	305.0 (SD 158.7)	< 0.001*
Trauma centre[¥]						
Level 1	2 (12.5%)	7 (8.4%)	6 (4.5%)	1 (0.3%)	16 (6.0%)	
Level 2	3 (18.8%)	21 (25.3%)	10 (7.8%)	0 (0.0%)	34 (12.8%)	
Level 3	1 (6.3%)	3 (3.6%)	13 (9.8%)	0 (0.0%)	17 (6.4%)	
Level 4	0 (0.0%)	0 (0.0%)	3 (2.2%)	1 (0.3%)	4 (1.5%)	
Non-trauma center	10 (62.5%)	52 (62.7%)	100 (75.8%)	32 (94.1%)	194 (73.2%)	< 0.001**
Rural setting						
Yes	0 (0.0%)	5 (6.1%)	18 (14.3%)	8 (23.5%)	31 (12.1%)	
No	15 (100.0%)	77 (93.9%)	108 (85.7%)	26 (76.5%)	226 (87.9%)	< 0.001**
Teaching hospital						
Yes	11 (73.3%)	57 (69.5%)	103 (81.7%)	27 (79.4%)	198 (77.0%)	
No	4 (26.7%)	25 (30.5%)	23 (18.3%)	7 (20.6%)	59 (23.0%)	< 0.001**

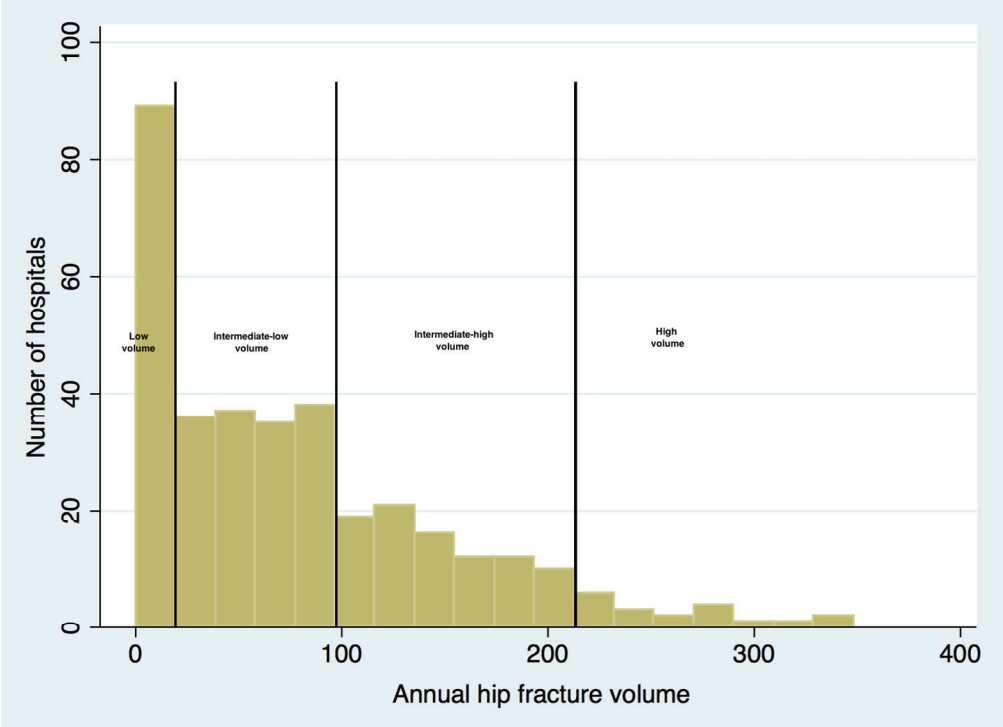
*Kruskall-Wallis one-way analysis of variance; **Chi squared test; [¥]Five institutions changed trauma center designation between 2007 and 2012.

Table 3: Unadjusted hip fracture outcomes by hospital case volume						
	High volume	**Intermediate-high volume**	**Intermediate-low volume**	**Low volume**	**Total cohort**	**P**
Median time to theatre (days)	1.0 (IQR 0.0 to 2.0)	1.0 (0.0 to 1.0)	1.0 (1.0 to 2.0)	1.0 (1.0 to 2.0)	1.0 (0.0 to 2.0)	< 0.001*
Median length of stay (days)	4.0 (IQR 4.0 to 6.0)	5.0 (4.0 to 6.0)	5.0 (4.0 to 7.0)	6.0 (4.0 to 8.0)	5.0 (4.0 to 6.0)	< 0.001*
Discharge destination						
Home	749 (4.5%)	2,060 (4.4%)	1,610 (6.3%)	99 (12.5%)	4,518 (5.1%)	
Short-term hospital	38 (0.2%)	186 (0.4%)	239 (0.9%)	10 (1.3%)	473 (0.5%)	
Skilled nursing facility	14,431 (86.7%)	39,992 (86.3%)	21,255 (83.4%)	617 (77.9%)	76,295 (85.5%)	
Home Health Care	1,423 (8.6%)	4,089 (8.8%)	2,361 (9.3%)	66 (8.3%)	7,939 (8.9%)	
Against Medical Advice	7 (0.0%)	21 (0.1%)	22 (0.1%)	22 (0.1%)	7 (0.0%)	< 0.001**
In-hospital mortality	313 (1.8%)	886 (1.9%)	450 (1.7%)	14 (1.7%)	1,663 (1.8%)	0.585**
Unplanned re-admission	1,987 (11.9%)	4,971 (10.7%)	2,829 (11.0%)	101 (12.6%)	9,888 (11.0%)	< 0.001**
Post-operative sequelae						
All	1,650 (9.7%)	5,046 (10.6%)	2,727 (10.5%)	90 (11.0%)	9,513 (10.4%)	< 0.001**
VTE	400 (2.6%)	1,262 (2.7%)	515 (2.0%)	17 (2.1%)	2,194 (2.4%)	< 0.001**
Decubitus ulcers	1,029 (6.1%)	3,274 (6.9%)	1,874 (7.2%)	60 (7.3%)	6,237 (6.8%)	< 0.001**
Pneumonias	320 (1.9%)	951 (2.0%)	575 (2.20%)	20 (2.5%)	1,866 (2.0%)	< 0.001**

*Kruskall-Wallis one-way analysis of variance; **Chi squared test

Table 4: Adjusted hip fracture outcomes by hospital case volume*		
Outcome	**Category**	**Predicted mean difference (95% CI)**
Time to theatre*	High volume (reference)	-
	Intermediate-high volume	0.34 (0.05 to 0.62)
	Intermediate-low volume	1.14 (0.80 to 1.48)
	Low volume	1.96 (1.20 to 2.73)
Length of stay*	High volume (reference)	-
	Intermediate-high volume	0.03 (-0.12 to 0.17)
	Intermediate-low volume	0.32 (0.13 to 0.52)
	Low volume	0.70 (0.38 to 1.03)
		Adjusted OR (95% CI)
In-hospital mortality**	High volume (reference)	1.00
	Intermediate-high volume	1.02 (0.86 to 1.22)
	Intermediate-low volume	1.00 (0.79 to 1.27)
	Low volume	1.28 (0.74 to 2.22)
Unplanned readmission**	High volume (reference)	1.00
	Intermediate-high volume	0.86 (0.75 to 0.98)
	Intermediate-low volume	0.88 (0.73 to 1.05)
	Low volume	1.06 (0.65 to 1.73)
Post-operative sequelae**	High volume (reference)	1.00
	Intermediate-high volume	1.16 (0.95 to 1.41)
	Intermediate-low volume	1.24 (0.99 to 1.55)
	Low volume	1.45 (0.97 to 2.15)

*generalized linear regression model (output as predicted mean difference with 95% confidence intervals); ** multivariable logistic regression (output as adjusted odds ratios with 95% confidence intervals)



A histogram showing the frequency of hospitals in California by annual hip fracture case volume and selected category thresholds.
593x431mm (72 x 72 DPI)

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any pre-specified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4, 5, 6, 7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	4
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5,6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	5,6

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	6
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA -
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Follow-up limited to 30-days, p5,6.
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	NA
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6 and Table 1
		(*b*) Report category boundaries when continuous variables were categorized	5
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Hospital Case Volume and Outcomes for Proximal Femoral Fractures in the United States: an Observational Study

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Hospital Case Volume and Outcomes for Proximal Femoral Fractures in the United States: an Observational Study.

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Key words

Minimum volume thresholds; volume-outcome; hip fracture

Word count

2,657

Abstract

Objective: To explore whether older adults with isolated hip fractures benefit from treatment in high-volume hospitals.

Design: Population-based observational study.

Setting: All acute hospitals in California, USA.

Participants: All individuals aged ≥65 that underwent an operation for an isolated hip fracture in California between 2007 and 2011. Patients transferred between hospitals were excluded.

Primary and secondary outcomes: Quality indicators (time to surgery) and patient outcomes (length of stay, in-hospital mortality, unplanned 30-day re-admission, and selected complications).

Results: 91,401 individuals satisfied the inclusion criteria. Time to operation and length of stay were significantly prolonged in low volume hospitals, by 1.96 (95% CI 1.20-2.73) and 0.70 (0.38-1.03) days respectively. However, there were no differences in clinical outcomes, including in-hospital mortality, 30-day re-admission, and rates of pneumonia, pressure ulcers, and venous thromboembolism.

Conclusion: These data suggest that there is no patient safety imperative to limit hip fracture care to high-volume hospitals.

Strengths and limitations

- The California State Inpatient Database captures 98% of patient admissions to acute hospitals in a state of over 39 million people.
- Unique patient and hospital identifiers permitted calculation of annual case volumes and tracking patient readmissions to any hospital in California.
- This methodological approach adjusted for important patient- and hospital-level characteristics but may be limited by residual confounding.

Introduction

There are approximately 250,000 hip fractures in the United States[1] every year, which are a major cause of mortality and morbidity. High provider case volumes have been associated with improved outcomes across a range of surgical procedures, including major arterial vascular surgery[2], oesophageal resection[3], and elective arthroplasty[4,5]. A small number of studies have explored the effect of hospital volume on hip fracture outcomes[6-11]. However, these reports reached inconsistent conclusions, with only two identifying a relationship between hospital volume and outcomes[7,10]. These studies predominantly used cross-sectional datasets that could not measure longitudinal outcomes such as re-admission to hospital and complications following discharge[6,8,10]. They also included cases from over fifteen years ago[7] that are unlikely to reflect modern hip fracture management. Contemporary hip fracture treatment emphasizes the use of standardized clinical pathways[12], formal geriatric assessment[13], and early operation to expedite mobility[14]. It is possible that the increasing standardization of hip fracture management will have influenced any relationship between clinical outcomes and provider volume.

A recent systematic review called for more studies aimed at characterizing volume-outcome relationships for specific orthopaedic patient populations[15]. This is necessary to determine the optimal setting for hip fracture patients and to inform both pre-hospital triage and inter-hospital referral pathways.

The aim of this study was to explore associations between case volume and outcomes using a comprehensive population database.

Methods

Data source

Hospital discharge records were analyzed from the California State Inpatient Database (SID) 2007-2011. The SID is managed by the Healthcare Cost and Utilization Project (HCUP) which is an initiative of the US Agency for Healthcare Research and Quality (AHRQ) intended both for administrative and research purposes. It includes all inpatient discharge records from 98% of hospitals in California[16], regardless of payment source. Unique patient identifiers allow individuals to be tracked between admissions, so permitting longitudinal analysis of patient-level data. The SID was linked to the American Hospital Association (AHA) Annual Survey Database so that specific hospital characteristics (e.g. trauma centre status) could be included within the analysis.

Study population

Patients with a primary or secondary International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) diagnosis code indicating "fracture of neck of femur" (820.0-820.9) were extracted from the SID. Patients were excluded if they were aged <65 years, treated non-operatively, subject to an inter-hospital transfer, or had any other injury with an Abbreviated Injury Scale (AIS) severity score ≥2. Age 65 was chosen to exclude higher energy hip fractures in younger patients and because individuals aged ≥65 in the US are universally insured through Medicare. Patients transferred between hospitals were excluded to minimize selection bias.

Patient and hospital characteristics

Extracted patient characteristics included age, sex, race (white, black, Hispanic, other), payment source (publicly funded, private insurance, self-pay), and weekend admission.

Abbreviated Injury Scale and Charlson co-morbidity indices were generated using the ICDPIC and CHARLSON modules respectively in Stata Statistical Software Release 13.0 (College Station, Texas, USA). The Charlson co-morbidity index (CCI) is a weighted score derived from 22 co-morbid diagnoses. It is the most widely used co-morbidity score for analyzing administrative datasets[17] and has been shown to predict both resource utilization[18] and mortality[19] in hip fracture populations.

Hospital characteristics included trauma centre level (1-4, with level 1 representing large regional trauma centres), teaching status (defined as hosting a physician training programme accredited by the Accreditation Council for Graduate Medical Education [ACGME]), and hospital bed size (categorized as <200 and ≥200 beds).

Unique identifiers within the SID were used to determine the annual hip fracture case volume of each hospital. Visual inspection of a histogram (number of hip fracture patients versus the annual volume at each treating hospital) revealed four distinct groups (Figure 1). The four volume groups were defined as: low <20, intermediate-low 20-99, intermediate-high 100-215, and high >215 cases per year. Although data from all categories are reported, the principal comparison in this paper was between high and low volume hospitals.

Outcome measures

Outcome measures included length of stay, in-hospital mortality, unplanned re-admission, and selected complications experienced as an inpatient or within 30 days post-discharge from the hospital. Both days to operation and length of stay were measured from time of admission rather than time of injury, which is not available from

the SID. Complications were identified by ICD-9-CM codes as venous thromboemboli (deep vein thrombosis 453.4, pulmonary embolus 415.1, pneumonias (480-488), and decubitus ulcers (707.0). These complications were also considered together as a single composite outcome. Only patients discharged alive from the hospital were eligible for calculating length of stay and 30-day re-admission. Re-admissions and sequelae were captured even if the patient presented to a different (non-index) hospital in the state of California rather than the institution that treated their hip fracture.

Sensitivity analysis

As comparatively few patients (and associated adverse events) were anticipated in the low volume category, a sensitivity analysis was planned with low and intermediate-low volume categories combined before comparison with the two higher volume groups.

Statistical analysis

Outcome variables were compared between the volume categories using Chi-square tests for categorical variables and Kruskall-Wallis one-way analysis of variance for non-normally distributed continuous variables. Multivariable logistic regression models were used to examine the risk-adjusted associations of case volume with mortality, unplanned 30-day re-admission, and post-operative complications. Co-variates included in regression models were age, sex, race, payment source, weighted CCI (as a continuous co-variate), discharge destination, hospital bed size, teaching status, and trauma centre level. All models accounted for clustering of patients within hospitals and used robust standard errors.

Length of stay (LOS) presented as right-skewed data and so risk-adjusted associations were explored using generalized linear regression with a gamma distribution[20] and link log followed by post-estimation of average marginal effects to attain predicted mean differences in LOS. The threshold for statistical significance was set at two-sided $p < 0.05$. Statistical analyses were performed using Stata 13.0. The Partners Human Research Committee approved the study protocol (IRB 2014P002072/BWH).

Results

Patient and hospital characteristics

There were 91,401 patients in the final cohort, demographic and admission characteristics for which are shown in Table 1. The mean age was 81.7 (SD 8.3) years. The patients were predominantly female (71.7%), white (81.0%), publicly insured (91.1%), admitted during the working week (72.6%), and had a CCI <2 (68.7%). A greater proportion of non-white and male patients were treated in lower volume hospitals. Patients were more commonly treated at a high volume hospital if presenting during the weekend (27.4% vs 21.4%, $p < 0.001$).

Within California, there were 257 individual hospitals that treated hip fractures, characteristics of which are described in Table 2. They were predominantly teaching institutions (77.0%) without trauma centre designation (73.2%) and located in a non-rural setting (87.9%). The mean annual case volume was 79.1 (SD 72.6). However, this varied significantly between the categories: low 5.2 (SD 6.0), intermediate-low 59.0 (SD 22.6), intermediate-high 150.0 (SD 34.5), and high volume 276.0 (SD 37.5) cases per year ($p < 0.001$). A higher proportion of low volume hospitals were rurally situated (23.5% vs 0.0%, $p < 0.001$) and maintained an accredited residency program (79.4% vs

73.3%, p < 0.001) but a lower proportion were designated as a trauma centre (26.8% vs 33.3%, p < 0.001). Low volume hospitals were also smaller in size, ranging from a mean of 109.3 beds in the low volume to 348.8 in the high volume category (p < 0.001).

Clinical outcomes

The unadjusted outcomes are summarized in Table 3 and results of the multivariable regression analyses in Table 4.

Time to operation

The overall median time to the operating theatre was 1.0 days (IQR 0.0 to 2.00). In the unadjusted analysis, low volume hospitals had a longer time to theatre (median 1, 90th percentile 3 days) than high volume hospitals (median 1, 90th percentile 2 days) (p < 0.001). Within a generalized linear regression model, adjusted surgical delay was inversely associated with hospital volume (p < 0.001). This was a stepwise association with a higher predicted mean difference observed in each successive volume category relative to high volume hospitals: intermediate-high 0.34 (95% CI 0.05 to 0.62), intermediate-low 1.14 (0.80 to 1.48), and low 1.96 (1.20 to 2.73). Patients in the lowest volume hospitals therefore reached the operating theatre almost two days later than those in the highest volume category (p < 0.001).

Length of stay

Median LOS was 5.0 (IQR 4.0 to 6.0) days but this was inversely associated with case volume in both unadjusted and adjusted analyses. In the multivariable regression model, there was no significant difference between the two highest volume categories. However, LOS in the intermediate-low volume and low volume groups were 0.32 and

0.70 days longer respectively. A higher proportion of patients were discharged to another care facility from high volume hospitals than from low volume hospitals (86.9% vs 79.2%, p < 0.001).

In-hospital mortality

There were 1,663 in-hospital deaths in the cohort, with an overall mortality of 1.8%. There were no significant differences between volume categories in terms of in-hospital mortality, either in the unadjusted (p = 0.585) or adjusted (p = 0.380) analyses. The sensitivity analysis (high volume versus combined low and intermediate-low volume hospitals) also did not detect any difference between the combined low volume and high volume categories (p = 0.964).

30-day unplanned re-admissions

A total of 9,888 (11.0%) patients required unplanned re-admission to hospital within 30 days of discharge. Rates of re-admission varied between the groups with the highest rate observed in the low volume category (12.6%, p = 0.042). In the multivariable analysis, there was no consistent association between case volume and likelihood of re-admission (OR 1.06, 95% CI 0.65 to 1.73). This finding was confirmed by the sensitivity analysis with combined low volume categories (OR 0.88, 0.74 to 1.05).

Hip fracture sequelae

Major hip fracture sequelae (venous thromboembolism, decubitus ulcers, and pneumonia) were reported in 9,513 cases (10.4%). They occurred more commonly in the lowest volume category (11.0 vs 9.7%, p < 0.001). However, this difference was not significant in the multivariable regression analysis (Table 4).

There were 2,194 patients with venous thromboembolism (2.4%), 6,237 with decubitus ulcers (6.8%), and 1,866 with pneumonia (2.0%). In the unadjusted analyses, decubitus ulcers and pneumonia occurred more commonly in low volume hospitals while VTE occurred in high volume hospitals (all $p < 0.001$). However, there were no differences in either the primary adjusted (Table 4) or sensitivity analyses.

Discussion

This study found evidence of less efficient hip fracture treatment (delayed operation and prolonged LOS) in low volume hospitals. However, it did not identify any relationship between volume and clinical outcomes for patients with hip fractures. This is the first study to examine the relationship between hospital case volume and hip fracture outcomes using a contemporary population dataset. Importantly, post-discharge complications could be identified if they required admission to any hospital in the state. Previous studies are dated or used cross-sectional databases that could not facilitate longitudinal follow-up of patients between institutions[6-11].

In this study, the mean hip fracture case volume was 79.1 per year; with a relatively high number of low volume (<20 per year) hospitals. Although the mean annual case volume in California was higher than previously described across the US[7,21], hip fracture cases may be more concentrated in other settings. For example, in the United Kingdom, only six hospitals reported annual case volumes <100 in 2014[22].

Although two previous studies have reported an inverse relationship between hospital volume and hip fracture mortality[7,10], no such finding emerged from this comprehensive

population dataset. This also conflicts with reports from other distinct surgical populations[2-5]. One possibility is that hip fractures are commonly encountered during orthopaedic training[23] and so surgeons should therefore be familiar with the needs of this patient group, even in low volume centres. This might explain why hip fractures do not exhibit the volume-outcome relationship that has been identified for more specialized populations, e.g. those undergoing revision arthroplasty surgery[4,5]. Hip fracture treatment is also increasingly driven by protocols and pathways, which might reduce variation between hospitals[12,24].

There was however evidence of higher quality care in high volume centres. These include reduced delay to the operating theatre and length of stay. One possible explanation for this finding is that staff expertise and clinical pathways improve with the experience that results from treating high numbers of similar patients. For example, pathways and processes might have been more developed at higher volume centres. It is important that, although length of stay was shorter at high volume centres, patients were more likely to be discharged to another healthcare facility than their own home. This suggests that relationships with other institutions (such as skilled nursing facilities) may contribute to achieving a shorter length of stay. It is also a reminder that discharge from hospital does not necessarily represent the end of each patient journey.

An alternative explanation is proposed by the "selective referrals" hypothesis, which claims that high quality hospitals are referred a greater number of patients[9]. This reverses the presumed direction of causation between volume and outcome. In this study, we controlled for some fixed hospital characteristics (e.g. trauma centre status) but unknown hospital-level founding factors might have persisted. However, patients

transferred between institutions were excluded to minimize the "selective referrals" effect.

Although prolonged operation time has been associated with hip fracture sequelae (venous thromboembolism, pneumonia, and decubitus ulcers)[25], these were not over-represented in the lower volume centres.

This study is not without limitations. As the SID is a retrospective dataset, unknown confounding factors might have been omitted from our multivariable regression models. In particular, it was not possible to determine the role of individual surgeon case volume. Previous studies have suggested that surgeon volume may be even more important than hospital volume on patient outcomes. In one series of 173,508 elderly patients undergoing hip hemiarthroplasty for fracture, surgeons in the lowest volume category had an 18% increased mortality compared with those in the highest[10]. It also is known that low volume surgeons cluster in low volume hospitals across a range of surgical procedures[26,27]. However, we accounted for clustering of fixed hospital-level characteristics in the multivariable regression analysis, which should have controlled for such differences. Although we found no hospital-level effect, it is still possible that low volume surgeons could have worse mortality outcomes, even in the absence of hospital-level differences. Although the California SID does not include the unique surgeon identifiers that would be necessary to calculate surgeon volume, this may be available in other datasets. For example, other state inpatient databases include unique surgeon identifiers that could be used to explore interactions between surgeon and hospital volume. The California SID was selected for this study because its unique patient identifier variable permitted analysis of readmissions to all hospitals in the state.

Further datasets may also be sought that can be linked to public death records so as to track deaths occurring outside of hospital. This is important because our study was unable to identify systematic differences in long-term outcomes (e.g. 12 month survival) that might be more important to patients than 30-day readmission.

Conclusion

In light of these findings, there is no patient safety imperative to discourage low volume hospitals from treating patients with hip fractures. However, our data did suggest that patients treated in low-volume hospitals are less likely to undergo prompt operation than those in high-volume institutions. Further work should attempt to determine whether volume could be associated with process differences, costs, or long-term outcomes for older adults with hip fractures.

Author contributions

DM conceived the study idea, undertook the statistical analysis, and drafted the manuscript. OO, BG, CZ, MH, DP, AS and MC contributed to the study design, interpretation of findings, and made critical revisions to the manuscript.

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Competing interests

No competing interests.

Data sharing agreement

No additional data available.

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Table 1: Demographic characteristics of the final hip fracture cohort						
	High volume	**Intermediate-high volume**	**Intermediate-low volume**	**Low volume**	**Total cohort**	**P**
Patients	16,992	47,513	26,079	817	91,401	
Age	82.1 (SD 8.2)	81.9 (SD 8.2)	81.2 (SD 8.4)	78.9 (SD 8.8)	81.7 (SD 8.3)	< 0.001*
Sex						
Male	4,764 (28.1%)	13,251 (28.0%)	7,480 (28.9%)	255 (32.6%)	25,750 (28.3%)	
Female	12,172 (71.9%)	34,092 (72.0%)	18,415 (71.1%)	527 (67.4%)	65,206 (71.7%)	0.003**
Race						
White	14,784 (88.5%)	38,284 (82.2%)	18,674 (74.6%)	426 (58.6%)	72,168 (81.0%)	
Black	209 (1.3%)	862 (1.9%)	771 (3.1%)	23 (3.2%)	1,865 (2.1%)	
Hispanic	971 (5.8%)	4,452 (9.6%)	2,692 (11.8%)	245 (33.7%)	8,630 (9.7%)	
Other	736 (4.4%)	2,997 (6.4%)	2,626 (10.5%)	33 (4.5%)	6,392 (7.2%)	< 0.001**
Payment source						
Self-pay	116 (0.7%)	210 (0.4%)	253 (0.6%)	5 (0.6%)	484 (0.5%)	
Private	1,192 (7.0%)	3,678 (7.7%)	1,825 (7.0%)	56 (6.9%)	6,761 (7.4%)	
Public	15,583 (91.7%)	43,168 (90.9%)	23,730 (91.0%)	731 (89.5%)	83,212 (91.1%)	
Other	101 (0.6%)	451 (1.0%)	361 (1.4%)	25 (3.1%)	938 (1.0%)	< 0.001**
Weekend admission						
Yes	4,654 (27.4%)	13,158 (27.7%)	7,039 (27.0%)	175 (21.4%)	25,026 (27.4%)	
No	12,338 (72.6%)	34,355 (72.3%)	19,040 (73.0%)	642 (78.6%)	66,375 (72.6%)	< 0.001**
Charlson index						
<2	11,767 (69.3%)	32,455 (68.3%)	18,007 (69.1%)	589 (72.1%)	62,818 (68.7%)	
≥2	5,225 (30.8%)	15,058 (31.7%)	8,072 (31.0%)	228 (27.9%)	28,583 (31.3%)	0.009**

*Kruskall-Wallis one-way analysis of variance; **Chi squared test

Table 2: Characteristics of hospitals treating patients in each volume category

	High volume	Intermediate-high volume	Intermediate-low volume	Low volume	Total cohort	P
N	15	82	126	34	257	
Mean annual volume	276 (SD 37.5)	150 (SD 34.5)	59 (SD 22.6)	5.2 (SD 6.0)	79.1 (SD 72.6)	< 0.001*
Hospital bed size	348.8 (SD 142.7)	229.3 (SD 145.8)	137.9 (SD 100.3)	109.3 (SD 117.6)	305.0 (SD 158.7)	< 0.001*
Trauma centre[¥]						
Level 1	2 (12.5%)	7 (8.4%)	6 (4.5%)	1 (0.3%)	16 (6.0%)	
Level 2	3 (18.8%)	21 (25.3%)	10 (7.8%)	0 (0.0%)	34 (12.8%)	
Level 3	1 (6.3%)	3 (3.6%)	13 (9.8%)	0 (0.0%)	17 (6.4%)	
Level 4	0 (0.0%)	0 (0.0%)	3 (2.2%)	1 (0.3%)	4 (1.5%)	
Non-trauma center	10 (62.5%)	52 (62.7%)	100 (75.8%)	32 (94.1%)	194 (73.2%)	< 0.001**
Rural setting						
Yes	0 (0.0%)	5 (6.1%)	18 (14.3%)	8 (23.5%)	31 (12.1%)	
No	15 (100.0%)	77 (93.9%)	108 (85.7%)	26 (76.5%)	226 (87.9%)	< 0.001**
Teaching hospital						
Yes	11 (73.3%)	57 (69.5%)	103 (81.7%)	27 (79.4%)	198 (77.0%)	
No	4 (26.7%)	25 (30.5%)	23 (18.3%)	7 (20.6%)	59 (23.0%)	< 0.001**

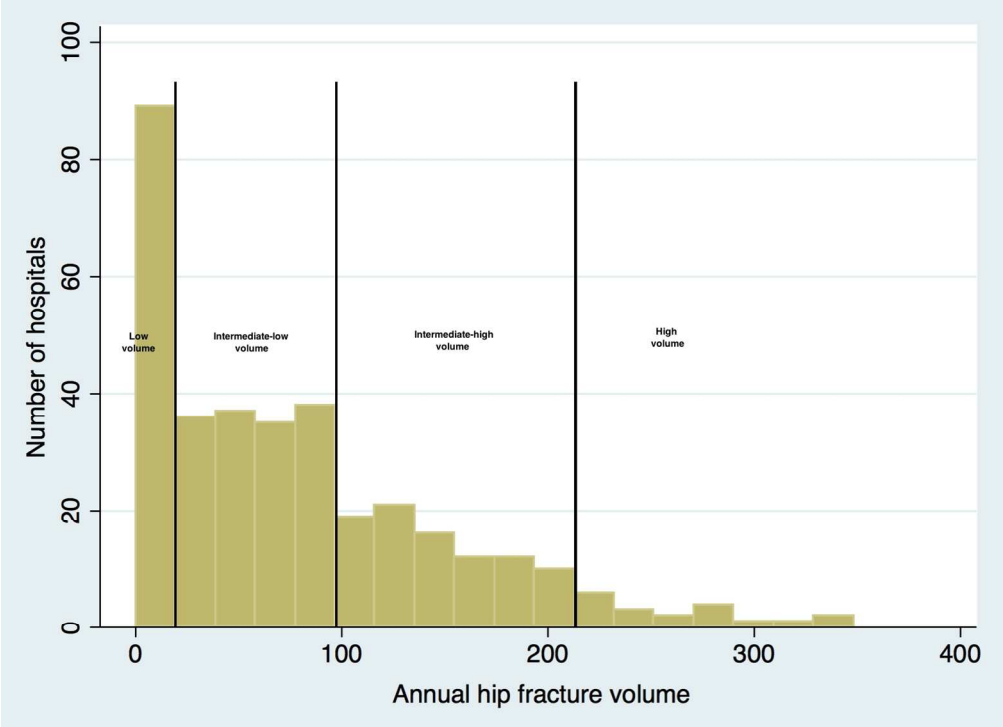
*Kruskall-Wallis one-way analysis of variance; **Chi squared test; [¥]Five institutions changed trauma center designation between 2007 and 2012.

Table 3: Unadjusted hip fracture outcomes by hospital case volume						
	High volume	**Intermediate-high volume**	**Intermediate-low volume**	**Low volume**	**Total cohort**	**P**
Median time to theatre (days)	1.0 (IQR 0.0 to 2.0)	1.0 (0.0 to 1.0)	1.0 (1.0 to 2.0)	1.0 (1.0 to 2.0)	1.0 (0.0 to 2.0)	< 0.001*
Median length of stay (days)	4.0 (IQR 4.0 to 6.0)	5.0 (4.0 to 6.0)	5.0 (4.0 to 7.0)	6.0 (4.0 to 8.0)	5.0 (4.0 to 6.0)	< 0.001*
Discharge destination						
Home	749 (4.5%)	2,060 (4.4%)	1,610 (6.3%)	99 (12.5%)	4,518 (5.1%)	
Short-term hospital	38 (0.2%)	186 (0.4%)	239 (0.9%)	10 (1.3%)	473 (0.5%)	
Skilled nursing facility	14,431 (86.7%)	39,992 (86.3%)	21,255 (83.4%)	617 (77.9%)	76,295 (85.5%)	
Home Health Care	1,423 (8.6%)	4,089 (8.8%)	2,361 (9.3%)	66 (8.3%)	7,939 (8.9%)	
Against Medical Advice	7 (0.0%)	21 (0.1%)	22 (0.1%)	22 (0.1%)	7 (0.0%)	< 0.001**
In-hospital mortality	313 (1.8%)	886 (1.9%)	450 (1.7%)	14 (1.7%)	1,663 (1.8%)	0.585**
Unplanned re-admission	1,987 (11.9%)	4,971 (10.7%)	2,829 (11.0%)	101 (12.6%)	9,888 (11.0%)	< 0.001**
Post-operative sequelae						
All	1,650 (9.7%)	5,046 (10.6%)	2,727 (10.5%)	90 (11.0%)	9,513 (10.4%)	< 0.001**
VTE	400 (2.6%)	1,262 (2.7%)	515 (2.0%)	17 (2.1%)	2,194 (2.4%)	< 0.001**
Decubitus ulcers	1,029 (6.1%)	3,274 (6.9%)	1,874 (7.2%)	60 (7.3%)	6,237 (6.8%)	< 0.001**
Pneumonias	320 (1.9%)	951 (2.0%)	575 (2.20%)	20 (2.5%)	1,866 (2.0%)	< 0.001**

*Kruskall-Wallis one-way analysis of variance; **Chi squared test

Table 4: Adjusted hip fracture outcomes by hospital case volume*		
Outcome	**Category**	**Predicted mean difference (95% CI)**
Time to theatre*	High volume (reference)	-
	Intermediate-high volume	0.34 (0.05 to 0.62)
	Intermediate-low volume	1.14 (0.80 to 1.48)
	Low volume	1.96 (1.20 to 2.73)
Length of stay*	High volume (reference)	-
	Intermediate-high volume	0.03 (-0.12 to 0.17)
	Intermediate-low volume	0.32 (0.13 to 0.52)
	Low volume	0.70 (0.38 to 1.03)
		Adjusted OR (95% CI)
In-hospital mortality**	High volume (reference)	1.00
	Intermediate-high volume	1.02 (0.86 to 1.22)
	Intermediate-low volume	1.00 (0.79 to 1.27)
	Low volume	1.28 (0.74 to 2.22)
Unplanned readmission**	High volume (reference)	1.00
	Intermediate-high volume	0.86 (0.75 to 0.98)
	Intermediate-low volume	0.88 (0.73 to 1.05)
	Low volume	1.06 (0.65 to 1.73)
Post-operative sequelae**	High volume (reference)	1.00
	Intermediate-high volume	1.16 (0.95 to 1.41)
	Intermediate-low volume	1.24 (0.99 to 1.55)
	Low volume	1.45 (0.97 to 2.15)

*generalized linear regression model (output as predicted mean difference with 95% confidence intervals); ** multivariable logistic regression (output as adjusted odds ratios with 95% confidence intervals)



A histogram showing the frequency of hospitals in California by annual hip fracture case volume and selected category thresholds.
142x103mm (300 x 300 DPI)

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any pre-specified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4, 5, 6, 7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	4
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5,6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	5,6

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	6
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA -
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Follow-up limited to 30-days, p5,6.
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	NA
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6 and Table 1
		(*b*) Report category boundaries when continuous variables were categorized	5
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.