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Are Case Volume and Facility Complexity Level Associated With Postoperative Complications After Hip Fracture Surgery in the Veterans Affairs Healthcare System?

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Abstract

Background Hospital-related factors associated with mortality and morbidity after hip fracture surgery are not completely understood. The Veterans Health Administration (VHA) is the largest single-payer, networked healthcare system in the country serving a relatively homogenous patient population with facilities that vary in size and resource

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Each author certifies that his or her institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.
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availability. These characteristics provide some degree of financial and patient-level controls to explore the association, if any, between surgical volume and facility resource availability and hospital performance regarding postoperative complications after hip fracture surgery.

Questions/purposes (1) Do VHA facilities with the highest complexity level designation (Level 1a) have a disproportionate number of better-than-expected performance outliers for major postoperative complications compared with lower-complexity level facilities? (2) Do VHA facilities with higher hip fracture surgical volume have a disproportionate number of better-than-expected performance outliers for major postoperative complications compared with lower-volume facilities?

Methods We explored the Veterans Affairs Surgical Quality Improvement Project (VASQIP) database from October 2001 to September 2012 for records of hip fracture surgery performed. Data reliability of the VASQIP database has been previously validated. We excluded nine of the 98 VHA facilities for contributing fewer than 30 records. The remaining 89 VHA facilities provided 23,029 records. The VHA designates a complexity level to each facility based on multiple criteria. We labeled facilities with a complexity Level 1a (38 facilities)–the highest achievable VHA designated complexity level—as high complexity; we labeled all other complexity level designations as low complexity (51 facilities). Facility volume was divided into tertiles: high (> 277 hip fracture procedures during the sampling frame), medium (204 to 277 procedures), and low (< 204 procedures). The patient population treated by low-complexity facilities was older, had a higher prevalence of severe chronic obstructive pulmonary disease (26% versus 22%, $p < 0.001$), and had a higher percentage of patients having surgery within 2 days of hospital admission (83% versus 76%, $p < 0.001$). High-complexity facilities treated more patients with recent congestive heart failure exacerbation (4% versus 3%, $p < 0.001$). We defined major postoperative complications as having at least one of the following: death within 30 days of surgery, cardiac arrest requiring cardiopulmonary resuscitation, new q-wave myocardial infarction, deep vein thrombosis and/or pulmonary embolism, ventilator dependence for at least 48 hours after surgery, reintubation for respiratory or cardiac failure, acute renal failure requiring renal replacement therapy, progressive renal insufficiency with a rise in serum creatinine of at least 2 mg/dL from preoperative value, pneumonia, or surgical site infection. We used the observed-to-expected ratio (O/E ratio)—a risk-adjusted metric to classify facility performance—for major postoperative complications to assess the performance of VHA facilities. Outlier facilities with 95% confidence intervals (95% CI) for O/E ratio completely less than 1.0 were labeled "exceed expectation;" those that were completely greater than 1.0 were labeled "below expectation." We compared differences in the distribution of outlier facilities between high and low-complexity facilities, and between high-, medium-, and low-volume facilities using Fisher's exact test.

Results We observed no association between facility complexity level and the distribution of outlier facilities (high-complexity: 5% exceeded expectation, 5% below expectation; low-complexity: 8% exceeded expectation, 2% below expectation; $p = 0.742$). Compared with high-complexity facilities, the adjusted odds ratio for major postoperative complications for low-complexity facilities was 0.85 (95% CI, 0.67–1.09; $p = 0.108$).

We observed no association between facility volume and the distribution of outlier facilities: 3% exceeded expectation and 3% below expectation for high-volume; 10% exceeded expectation and 3% below expectation for medium-volume; and 7% exceeded expectation and 3% below expectation for low-volume; $p = 0.890$). The adjusted odds ratios for major postoperative complications were 0.87 (95% CI, 0.73–1.05) for low- versus high-volume facilities and 0.89 (95% CI, 0.79–1.02] for medium- versus high-volume facilities ($p = 0.155$).

Conclusions These results do not support restricting facilities from treating hip fracture patients based on historical surgical volume or facility resource availability. Identification of consistent performance outliers may help health care organizations with multiple facilities determine allocation of services and identify characteristics and processes that determine outlier status in the interest of continued quality improvement.

Level of Evidence Level III, therapeutic study.

Introduction

Hip fractures are a major public health concern that generate substantial healthcare costs [3]. Multiple studies have reported patient factors associated with mortality [22, 29]. The relationship between hospital hip fracture surgical volume and mortality has been studied, but an association has not been consistently observed [5, 7-10, 24, 27, 30]. Most reports suggest that teaching facilities have lower risk-adjusted mortality after hip fracture treatment when compared with community facilities [18, 19, 26, 32, 34]. However, to our knowledge, no studies have examined the effect of a hospital's acuity level as an indication of resource availability and preparedness and its association with hip fracture mortality and postoperative morbidity.

The Veterans Health Administration (VHA) is the largest networked healthcare system in the country and may serve as a prototype for single-payer healthcare and bundled payment programs, which are increasing nationwide. The Veterans Affairs Surgical Quality Improvement Program (VASQIP) dataset has been validated for data reliability [6]. It was implemented in 1994 with the goal of monitoring quality and facilitating the implementation of improvement projects. Data are longitudinally maintained across all subspecialties across the VHA. There are advantages to exploring the VASQIP dataset. The VHA payment structure removes financial incentives for facilities to select patients, which may be a challenging confounder to account for when assessing facility performance [25]. Unique to the VHA is a complexity level designation for each facility that is related to the facility's resource availability; this aids investigation into resource availability and facility performance.

The endpoint of mortality is both important and unambiguous; as such, it is often used in clinical and health-systems research, including studies on hip fracture [5, 7-10, 19]. However, postoperative complications contributing to morbidity may also be important for patients and healthcare providers. A commonly used risk-adjusted metric to assess facility performance is the observed-to-expect ratio (O/E ratio) for mortality and morbidity [11, 12]. The potential association between facility volume and facility complexity level designation—which we use as a proxy for resource availability—and risk-adjusted major postoperative complications after hip fracture surgery has not been explored.

In this study, we asked: (1) Do VHA facilities with the highest complexity level designation (Level 1a) have a disproportionate number of better-than-expected performance outliers for major postoperative complications compared with lower-complexity level facilities? (2) Do VHA facilities with higher hip fracture surgical volume have a disproportionate number of better-than-expected performance outliers for major postoperative complications compared with lower-volume facilities?

Patients and Methods

This retrospective, comparative study was reviewed and approved by the institutional review board and local VHA research committee with a waiver of informed consent. The sample obtained from the VASQIP database consisted of patient records from October 2001 to September 2012.

Study Subjects (Patient Level)

Included in this dataset were orthopaedic trauma and elective THA and partial hip arthroplasties. Patients surgically treated for hip fractures were identified by the following current procedural terminology (CPT) codes: 27220, 27226, 27227, 27228, 27230, 27232, 27235, 27236, 27238, 27240, 27244, 27245, 27246, 27248, 27269, 27254, 27258, and 27269. We also included patients who were treated with a THA (CPT code: 27130) or a partial hip arthroplasty (CPT code: 27125) with concomitant international classification of diseases-9 (ICD-9) code indicating a hip fracture diagnosis: 733.1, 733.15, 733.42, 733.96, or between 820 – 820.91. We observed notable if small differences between patients treated by high-complexity facilities compared with those treated by low-complexity facilities. The age distribution of the cohort treated at low-complexity facilities skewed toward an older population; the population treated by low-complexity facilities had a slightly higher prevalence of severe COPD and a lower prevalence of congestive heart failure exacerbation within a month of surgery. A higher percentage of patients from low-complexity facilities had surgery within 48 hours of hospital admission (Table 1). A larger proportion of patients treated at high-volume centers were completely dependent on others to perform activities of daily living (Table 2).

Study Subjects (Facility Level; Hospital Characteristics)

To ensure adequate sample size for meaningful statistical analysis within each facility, we excluded nine facilities where surgeons performed fewer than 30 hip fracture procedures during the sampling time frame. Two hospital characteristics were available and of interest: (1) designated facility complexity level; and (2) facility hip fracture surgery volume. Each VHA hospital is assigned to one of five complexity level designations, which are high (Level 1), intermediate (Level 2), and standard (Level 3); high level is subdivided into 1a, 1b, and 1c. The criteria contributing to this classification includes: (1) the availability of subspecialty surgical programs (eg, cardiac surgery, neurosurgery); (2) supportive programs (such as interventional radiology or a polytrauma program); (3) intensive care unit level; (4) breadth of the physician training program; (5) grant funding for research; and (6) an estimate of the health risk of the population served by the VHA facility based on patient diagnosis grouping.

Balancing sample size considerations and assigning a rational demarcation for facility groupings, we labeled complexity Level 1a facilities "high" complexity and all other complexity level designations "low" complexity. In a separate analysis, we stratified facilities into tertiles with respect to surgical volume. Facilities contributing more than 277 records during the sampling time frame were considered high-volume facilities; we labeled facilities where surgeons performed between 204 to 277 procedures medium-volume; and fewer than 204 procedures were labeled low-volume (Table 3).

Accounting for All Patients

The VASQIP database provided a list of 47,477 patient records. Exclusion of nonhip fracture orthopaedic trauma, hip arthroplasty for osteoarthritis, records with missing procedures and diagnosis codes, and records from facilities that contributed fewer than 30 hip fracture procedures

Table 1. Preoperative characteristics and selected outcomes of the cohort (n = 23,029) stratified by facility complexity level

Characteristic	Entire cohort (n = 23,029) (number, %)	High complexity (n = 12,039) (number, %)	Low complexity (n = 10,990) (number, %)	p value
Age				< 0.001
≤ 60	4969 (22%)	2758 (23%)	2211 (20%)	
61-70	4300 (19%)	2284 (19%)	2016 (18%)	
71-80	6078 (26%)	3118 (26%)	2960 (27%)	
81-90	6900 (30%)	3498 (29.0%)	3402 (31%)	
> 90	782 (3%)	381 (3%)	401 (4%)	
Sex				
Male	22,028 (96%)	11,479 (95%)	10,549 (96%)	0.018
Female	1001 (4%)	560 (5%)	441 (4%)	
Race				< 0.001
White	15,722 (68%)	7728 (64%)	7994 (73%)	
Black	2705 (12%)	1491 (12%)	1214 (11%)	
Hispanic	994 (4%)	827 (7%)	167 (2%)	
Asian or Pacific Islander	53 (0.2%)	25 (0.2%)	28 (0.3%)	
Other or Unknown	3555 (15%)	1968 (16%)	1587 (14%)	
Chronic comorbidities				
Diabetes				0.846
No diabetes or diabetes controlled by diet alone	18,216 (79%)	9519 (79%)	8697 (79%)	
Oral agents	2366 (10%)	1229 (10%)	1137 (10%)	
Insulin	2447 (11%)	1291 (11%)	1156 (11%)	
Congestive heart failure within 30 days preoperatively	821 (4%)	482 (4%)	339 (3%)	< 0.001
Cerebral vascular accident	3865 (17%)	2058 (17%)	1807 (16%)	0.186
Transient ischemic attack	1120 (5%)	552 (5%)	568 (5%)	0.0429
Chronic obstructive pulmonary disease (COPD, severe) *	5398 (23%)	2596 (22%)	2802 (26%)	< 0.001
Hemiplegia	1480 (6%)	813 (7%)	667 (6%)	0.036
Ascites within 30 days preoperatively	195 (1%)	116 (1%)	79 (1%)	0.043
Weight loss (> 10% in 6 months preoperatively)	1202 (5%)	540 (5%)	662 (6%)	< 0.001
Bleeding disorders[†]	2000 (9%)	1039 (9%)	961 (9%)	0.779
Disseminated cancer	848 (4%)	440 (4%)	408 (4%)	0.822
Steroid use for chronic conditions within 30 days preoperatively	917 (4%)	448 (4%)	469 (4%)	0.419
Dyspnea[‡]				< 0.001
No dyspnea present	18,919 (83%)	10,157 (85%)	8762 (81%)	
With minimal exertion	3353 (15%)	1579 (13%)	1774 (16%)	
At rest	563 (3%)	228 (2%)	335 (3%)	
Functional health status within 30 days preoperatively				< 0.001
Independent	13,377 (58%)	7097 (59%)	6280 (57%)	
Partially dependent	7246 (32%)	3564 (30%)	3682 (34%)	
Totally dependent	2406 (10%)	1378 (11%)	1028 (10%)	
Acute preoperative conditions				

Table 1. continued

Characteristic	Entire cohort (n = 23,029) (number, %)	High complexity (n = 12,039) (number, %)	Low complexity (n = 10,990) (number, %)	p value
Open wound/wound infection	1130 (5%)	547 (5%)	583 (5%)	0.008
Delirium	1426 (6%)	634 (5%)	792 (7%)	< 0.001
Transfusion > 4 units PRBCs within 72 hours preoperatively	71 (0.3%)	35 (0.3%)	36 (0.3%)	0.636
Pneumonia	597 (3%)	291 (2%)	306 (3%)	0.081
Ventilator dependent during the 48 hours preoperatively	59 (0.3%)	35 (0.3%)	24 (0.2%)	0.299
Acute renal failure[§]	197 (1%)	123 (1%)	74 (1%)	0.004
Dialysis within 2 weeks preoperatively	479 (2%)	262 (2%)	217 (2%)	0.283
Preoperative sepsis within 48 hours preoperatively	235 (1%)	97 (1%)	138 (1%)	< 0.001
Do not resuscitate order present	1,882 (8%)	851 (7%)	1,031 (9%)	< 0.001
Disposition prior to admission				< 0.001
Home	18,154 (79%)	9554 (79%)	8600 (78%)	
Acute care facility transfer	1831 (8%)	978 (8%)	853 (8%)	
Nursing home	2806 (12%)	1365 (11%)	1441 (13%)	
Other	238 (1%)	142 (1%)	96 (1%)	
Surgery within 2 days of admission	18,244 (79%)	9101 (76%)	9143 (83%)	< 0.001
Pathologic fracture	2861 (12%)	1201 (11%)	1660 (14%)	< 0.001
Arthroplasty				< 0.001
Total	3268 (14%)	1369 (13%)	1899 (16%)	
Hemi	3132 (14%)	1674 (15%)	1458 (12%)	
Anesthesia type				< 0.001
General	17,262 (75%)	9910 (82%)	7352 (67%)	
Neuraxial	5447 (24%)	2003 (17%)	3444 (31%)	
Unknown	320 (1%)	126 (1%)	194 (2%)	
Selected outcomes				
Admission within 14 days of discharge	248 (1%)	112 (1%)	136 (1%)	0.417
Postoperative length of hospital stay among patients alive in 1 year	(n = 18,354)	(n = 9624)	(n = 8730)	< 0.001
≤ 3 days	3654 (20%)	1814 (19%)	1840 (21%)	
4-5 days	4059 (22%)	2068 (22%)	1991 (23%)	
6-9 days	4764 (26%)	2413 (25%)	2351 (27%)	
10-13 days	2506 (14%)	1341 (14%)	1165 (13%)	
≥ 14 days	3371 (18%)	1988 (21)	1383 (16%)	
At least one major postoperative complication[‖]	3083 (13%)	1442 (13%)	1641 (14%)	0.257
Incidence of the following major postoperative complications				
Death within 30 days of surgery	1624 (7%)	795 (7%)	829 (7%)	0.303
Cardiac arrest requiring cardiopulmonary resuscitation	340 (2%)	140 (1%)	200 (2%)	0.015
q-wave myocardial infarction within 30 days postoperatively	167 (1%)	77 (1%)	90 (1%)	0.675
Deep vein thrombosis	224 (1%)	112 (1%)	112 (1%)	0.493

Table 1. continued

Characteristic	Entire cohort (n = 23,029) (number, %)	High complexity (n = 12,039) (number, %)	Low complexity (n = 10,990) (number, %)	p value
Pulmonary embolus	152 (1%)	76 (1%)	76 (1%)	0.573
Intubation for longer than 48 hours postoperatively	394 (2%)	154 (1%)	240 (2%)	< 0.001
Reintubation	690 (3%)	298 (3%)	392 (3%)	0.016
New-onset renal replacement therapy (RRT)	125 (1%)	54 (1%)	71 (1%)	0.310
Renal insufficiency (> 2 mg/dL rise, but without need for RRT)	203 (1%)	73 (1%)	130 (1%)	< 0.001
Pneumonia	1185 (5%)	541 (5%)	644 (5%)	0.143
Surgical site infection (deep or superficial) or wound dehiscence	369 (2%)	168 (2%)	201 (2%)	0.395

*Severe COPD; COPD resulting in any one or more of the following: (1) functional disability from COPD (eg, inability to perform ADLs), (2) previous hospitalization for COPD treatment, (3) requires chronic bronchodilator therapy with oral or inhaled agents, (4) FEV1 of < 75% predicted on pulmonary function testing.
†bleeding disorder; any condition that places the patient at risk for excessive bleeding requiring hospitalization due to a deficiency of blood clotting elements (eg, vitamin K deficiency, hemophilia, thrombocytopenia, chronic anticoagulation therapy that has not been discontinued or reversed before surgery); chronic aspirin therapy was not considered a bleeding disorder.
‡75 records from high-complexity facilities and 119 records from low-complexity facilities had missing data for the 'Dyspnea' variable; BUN = blood urea nitrogen.
§acute renal failure; defined as increasing BUN, with urinary output of less than 500 cc/24 hours, and a rising creatinine above 3 mg/dL.
||major postoperative complication; includes at least one of the following: (1) death within 30 days of surgery, (2) cardiac arrest requiring CPR, (3) myocardial infarction, (4) DVT/PE, (5) failure to wean from ventilator after 48 hours, (6) reintubation for respiratory/cardiac failure, (7) progressive renal insufficiency – rise in creatinine > 2 mg/dL from preoperative value, but without renal replacement requirement, (8) acute renal failure requiring incident postoperative renal replacement therapy; FEV1 = forced expiratory volume in 1 second; CPR = cardiopulmonary resuscitation; DVT/PE = deep vein thrombosis/pulmonary embolus.

during the sampling time frame resulted in a final cohort of 23,029 records (Fig. 1).

Variable: Major Postoperative Complications

We defined major postoperative complications as having at least one of the following postoperative adverse conditions: (1) death within 30 days of surgery; (2) cardiac arrest requiring cardiopulmonary resuscitation; (3) new q-wave myocardial infarction; (4) deep vein thrombosis/pulmonary embolism; (5) ventilator dependence for at least 48 hours after surgery; (6) reintubation for respiratory or cardiac failure; (7) acute renal failure requiring renal replacement therapy; (8) progressive renal insufficiency with a rise in serum creatinine of at least 2 mg/dL from the preoperative value; (9) pneumonia; or (10) surgical site infection.

Description of Model to Assess Risk of Having a Major Postoperative Complication

We performed bivariate analysis of available preoperative variables. Variables associated with a major postoperative complication at a p value ≤ 0.10 in the bivariate model were retained for testing in the multivariable logistic regression model with backwards elimination (see Appendix, Supplemental Digital Content 1). To test for model discrimination and calibration, we performed 10-fold cross validation. The area under the receiver operating characteristic (ROC) curve (AUC) generated by the predicted probabilities from 10-fold cross validation was used to determine model discrimination. Model calibration was tested with the Hosmer-Lemeshow goodness-of-fit test. To visualize model calibration, we used the predicted probabilities and the observed rate of major postoperative complications to generate a calibration plot (see Appendix, Supplemental Digital Content 2).

Because each facility's results contribute to the reference population of facilities, a facility's major postoperative complication rate impacts not only its own observed value but also the expected value. Facilities with extreme results may affect the expected values and lead to misclassification based on the O/E ratio method of facility classification. We performed "leave-one-out" cross validation to assess this possibility. Each facility was "left-out" once while the prediction model was developed using all other facilities; we applied the prediction model to the "left-out" facility to generate predicted probabilities for its records. We compared each facility's predicted probability derived from the leave-one-out cross validation

Table 2. Preoperative characteristics and selected outcomes of the cohort (n = 23,029) stratified by facility surgical volume

Characteristic	High-volume (number, %)	Medium-volume (number, %)	Low-volume (number, %)	p value
Number of patients	13,240	7618	2171	
Age				< 0.001
≤ 60	2620 (20%)	1880 (25%)	469 (20%)	
61-70	2399 (18%)	1509 (20%)	392 (18%)	
71-80	3605 (27%)	1905 (25%)	568 (26%)	
81-90	4172 (32%)	2050 (27%)	678 (31%)	
> 90	444 (3%)	274 (4%)	64 (3%)	
Sex				
Male	12,675 (96%)	7280 (96%)	2073 (95%)	0.781
Female	565 (4%)	338 (4%)	98 (5%)	
Race				< 0.001
White	9191 (69%)	4915 (65%)	1616 (74%)	
Black	1408 (11%)	1116 (15%)	181 (8%)	
Hispanic	721 (5%)	254 (3%)	19 (1%)	
Asian or Pacific Islander	16 (0.1%)	30 (0.4%)	7 (0.3%)	
Other or unknown	1904 (14%)	1303 (17%)	348 (16%)	
Chronic comorbidities				
Diabetes				< 0.001
No diabetes or diabetes controlled by diet alone	10,374 (78%)	6123 (80%)	1719 (79%)	
Oral agents	1405 (11%)	711 (9%)	250 (12%)	
Insulin	1461 (11%)	784 (10%)	202 (9%)	
Congestive heart failure in 30 days preoperatively	522 (4%)	246 (3%)	53 (2%)	< 0.001
Cerebral vascular accident	2349 (18%)	1192 (16%)	324 (15%)	< 0.001
Transient ischemic attack	698 (5%)	326 (4%)	96 (4%)	0.004
Chronic obstructive pulmonary disease (COPD, severe)*	3262 (25%)	1615 (21%)	521 (24%)	< 0.001
Hemiplegia	860 (7%)	487 (6%)	133 (6%)	0.799
Ascites in 30 days preoperatively	126 (1%)	58 (1%)	11 (1%)	0.068
Weight loss (> 10% in 6 months preoperatively)	711 (5%)	382 (5%)	109 (5%)	0.491
Bleeding disorders[†]	1212 (9%)	613 (8%)	175 (8%)	0.013
Disseminated cancer	473 (4%)	300 (4%)	75 (3%)	0.336
Steroid use for chronic condition in 30 days preoperatively	501 (4%)	365 (5%)	91 (4%)	0.002
Dyspnea[‡]				< 0.001
No dyspnea present	10,722 (82%)	6390 (84%)	1807 (84%)	
With minimal exertion	2030 (16%)	1028 (14%)	295 (14%)	
At rest	334 (3%)	173 (2%)	56 (3%)	
Functional health status in 30 days preoperatively				< 0.001
Independent	7426 (56%)	4562 (60%)	1389 (64%)	
Partially dependent	4202 (32%)	2445 (32%)	599 (28%)	
Totally dependent	1612 (12%)	611 (8%)	183 (8%)	
Acute preoperative conditions				
Open wound/wound infection	592 (4%)	428 (6%)	110 (5%)	0.001

Table 2. continued

Characteristic	High-volume (number, %)	Medium-volume (number, %)	Low-volume (number, %)	p value
Delirium	821 (6%)	474 (6%)	131 (6%)	0.947
Transfusion > 4 units PRBCs in 72 hours preoperatively	37 (0.3%)	30 (0.4%)	4 (0.2%)	0.196
Pneumonia	303 (2%)	233 (3%)	61 (3%)	0.003
Ventilator dependent during the 48 hours preoperatively	35 (0.3%)	19 (0.3%)	5 (0.2%)	0.949
Acute renal failure[§]	130 (1%)	57 (1%)	10 (0.5%)	0.023
Dialysis within 2 weeks preoperatively	278(2%)	167 (2%)	34 (2%)	0.191
Preoperative sepsis in 48 hours preoperatively	120 (1%)	92 (1%)	23 (1%)	0.111
Do not resuscitate order present	1065 (8%)	617 (8%)	200 (9%)	0.174
Disposition prior to admission				< 0.001
Home	10,395 (79%)	6073 (79%)	1686 (78%)	
Acute care facility transfer	959 (7%)	681 (9%)	191 (9%)	
Nursing Home	1753 (13%)	777 (10%)	276 (13%)	
Other	133 (1%)	87 (1%)	18 (1%)	
Surgery within 2 days of admission	10,563 (80%)	5922 (78%)	1759 (81%)	< 0.001
Pathologic facture	1461 (11%)	1149 (15%)	251 (12%)	< 0.001
Arthroplasty				< 0.001
Total	1722 (13%)	1259 (17%)	287 (13%)	
Hemiarthroplasty	1598 (12%)	1166 (15%)	368 (17%)	
Anesthesia type				< 0.001
General	10,136 (77%)	5700 (75%)	1426 (66%)	
Neuraxial	2932 (22%)	1,94 (24%)	721 (33%)	
Unknown	172 (1%)	124 (2%)	24 (1%)	
Selected outcomes				
Admission within 14 days of discharge	150 (1%)	86 (1%)	12 (1%)	0.045
Postoperative length of hospital stay among patients alive in 1 year	n = 10,428	n = 6155	n = 1771	< 0.001
≤ 3 days	2009 (19%)	1207 (20%)	438 (25%)	
4 - 5 days	2410 (23%)	1290 (21%)	359 (20%)	
6 – 9 days	2730 (26%)	1568 (25%)	466 (26%)	
10 – 13 days	1350 (13%)	882 (14%)	274 (15%)	
≥ 14 days	1929 (18%)	1208 (20%)	234 (13%)	
At least one major postoperative complication[‖]	1870 (14%)	932 (12%)	281 (13%)	< 0.001
Incidence of the following major postoperative complication				
Death within 30 days of surgery	1003 (8%)	482 (6%)	139 (6%)	0.002
Cardiac arrest requiring cardiopulmonary resuscitation	215 (2%)	102 (1%)	23 (1%)	0.062
q-wave myocardial infarction within 30 days postoperatively	111 (1%)	42 (1%)	14 (1%)	0.056
Deep vein thrombosis	128 (1%)	79 (1%)	17 (1%)	0.565
Pulmonary embolus	89 (1%)	46 (1%)	17 (1%)	0.638

Table 2. continued

Characteristic	High-volume (number, %)	Medium-volume (number, %)	Low-volume (number, %)	p value
Intubation for longer than 48 hours postoperatively	235 (2%)	126 (2%)	33 (2%)	0.625
Reintubation	410 (3%)	222 (3%)	58 (3%)	0.491
New-onset renal replacement therapy (RRT)	73 (1%)	39 (1%)	13(1%)	0.870
Renal insufficiency (> 2 mg/dL rise, but without need for RRT)	141 (1%)	50 (1%)	12 (1%)	0.002
Pneumonia	717 (5%)	345 (5%)	123 (6%)	0.011
Surgical site infection (deep or superficial) or wound dehiscence	222 (2%)	116 (2%)	31 (1%)	0.552

*Severe COPD; COPD resulting in any one or more of the following: (1) functional disability from COPD (eg, inability to perform ADLs), (2) previous hospitalization for COPD treatment, (3) requires chronic bronchodilator therapy with oral or inhaled agents, (4) FEV1 of < 75% predicted on pulmonary function testing.
†bleeding disorder; any condition that places the patient at risk for excessive bleeding requiring hospitalization due to a deficiency of blood clotting elements (eg, vitamin K deficiency, hemophilia, thrombocytopenia, chronic anticoagulation therapy that has not been discontinued or reversed before surgery); chronic aspirin therapy was not considered a bleeding disorder.
‡154 records from high-volume facilities; 27 from medium-volume facilities; and 13 from low-volume facilities had missing data for 'Dyspnea' variable.
§acute renal failure; defined as increasing BUN, with urinary output of less than 500 cc/24 hours, and a rising creatinine above 3 mg/dL.
||major postoperative complication; includes at least one of the following: (1) death within 30 days of surgery, (2) cardiac arrest requiring CPR, (3) myocardial infarction, (4) DVT/PE, (5) failure to wean from ventilator after 48 hours, (6) reintubation for respiratory/cardiac failure, (7) progressive renal insufficiency – rise in creatinine > 2 mg/dL from preoperative value, but without renal replacement requirement, (8) acute renal failure requiring incident postoperative renal replacement therapy; PRBC = packed red blood cells; FEV1 = forced expiratory volume in 1 second; BUN = blood urea nitrogen; CPR = cardiopulmonary resuscitation; DVT/PE = deep vein thrombosis/pulmonary embolus.

method to the predicted probability derived from the model that used records from all facilities (see Appendix, Supplemental Digital Content 3).

Observed-to-Expected Ratio Metric

The primary metric of interest was the facility O/E ratio of a major postoperative complication. We used the predictive model to calculate a probability of having a major postoperative complication for each record. The expected number of major postoperative complications for a facility was calculated by adding the predicted probabilities of the records from that facility; if a facility performed 100 procedures with each procedure having a 1% probability of having an event, the facility is expected to have one event. To derive the O/E ratio, the observed number of major postoperative complications at a facility was divided by the expected number of major postoperative complications. We calculated the 95% confidence interval (CI) for the O/E ratio for each facility with the SAS 9.4 PROC STDRATE module (SAS Institute Inc, Cary, NC, USA) with Poisson distribution. We labeled facilities whose 95% CI straddled 1.0 as meeting expectation; those whose 95% CI was entirely < 1.0 were labeled

Table 3. Facility distribution by complexity level and hip fracture surgical volume

VHA-designated facility complexity levels	1a	1b	1c	2 (intermediate)	3 (standard)
High-volume	21	7	2	0	0
Medium-volume	14	7	6	2	0
Low-volume	3	5	7	14	1
	High complexity	Low complexity			

VHA-designated high-complexity facilities (Level 1) were subdivided into Levels 1a, 1b, and 1c; for our analyses, complexity Level 1a facilities were labeled high complexity; complexity Levels 1b, 1c were categorized with complexity Levels 2 (intermediate complexity by VHA designation) and 3 (standard complexity by VHA designation) as low complexity.

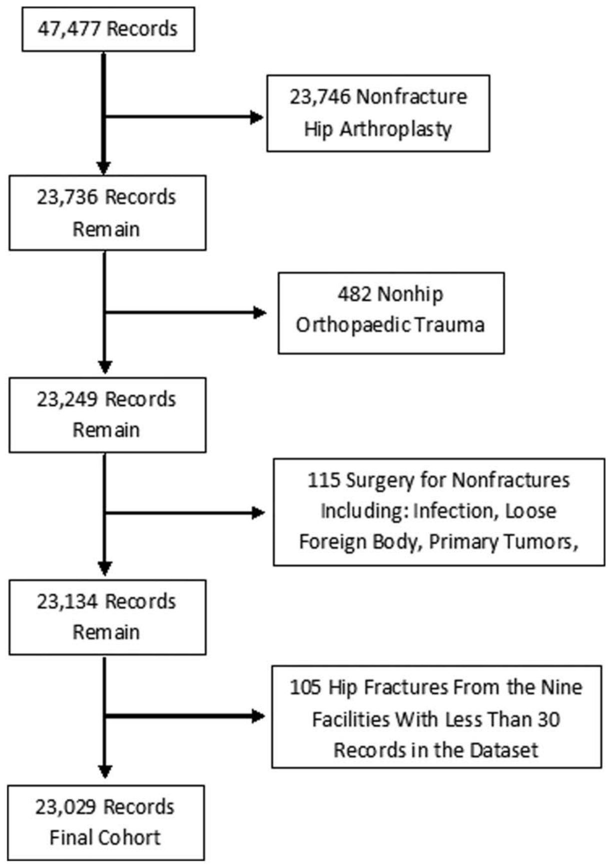

Fig. 1 This flow diagram summarizes the number of records that were excluded from the initial cohort of records.

exceeding expectation, while those facilities whose 95% CI was entirely > 1.0 were labeled below expectation. Facilities labeled exceeding expectation or below expectation were also referred to as outliers. We compared the distribution of outlier facilities between complexity levels and between facility surgical volume with the Fisher's exact test.

To assess the consistency of the observations by the O/E ratio methodology of classifying facility performance, we used multivariable hierarchical logistic regression modeling to assess facility performance and examined the association between facility complexity level and major postoperative complications. In these mixed models, we modeled facility complexity level and surgical volume as random effects.

Sources of Bias

Selection Bias

Because the estimated health risk ("sickness") of the entire patient population treated at a VHA facility is a criterion to determine complexity level, high-level facilities may have treated hip fracture surgery patients with more severe comorbidities. The risk assessment model to calculate a predicted probability of having a major postoperative complication attempts to account for patient factors associated with having a major postoperative event; however, because no model is perfect, there are certainly unknown and unaccounted for predictors.

Assessment Bias

Risk-adjusted facility metrics calculated from the VASQIP database are used for internal reporting and assessment purposes. Upgrading the patient risk profile improves facility performance metrics. The risk of this bias influencing the observations is mitigated by evidence of reliability of VASQIP data, including collections of preoperative comorbidities [6].

Additional Statistical Analysis Details

Descriptive statistics were expressed as frequency and percentage of the entire cohort. All comparisons were two-tailed, and $p < 0.05$ was considered statistically significant. We used SAS 9.4 software for all statistical analyses.

Results

VHA facilities with the highest complexity level designation did not have a higher proportion of facilities performing better than expected compared with lower complexity level designation facilities. The association between complexity Level 1a designation and major postoperative complications was null (OR, 0.85; 95% CI, 0.67–1.09; p = 0.108; Table 4).

VHA facilities with the highest hip fracture surgical volume did not have higher proportions of facilities performing better than expected compared with medium- and low-volume facilities. The association between surgical volume and major postoperative complications was null (low-volume versus high-volume: OR, 0.87; 95% CI, 0.73–1.05; medium-volume versus high-volume: OR, 0.89; 95% CI, 0.79– 1.02; p = 0.155; Table 5).

Other Relevant Findings

To validate the use of O/E ratio methodology, we applied multivariable hierarchical logistic regression modeling to classify facility performance. This method reclassified seven facilities from outlier to average performer, but no facilities classified as average by O/E ratio methodology were reclassified as an outlier.

Table 4. Distribution of facility performance for major postoperative complication among facility complexity level designation

Facility performance	O/E ratio methodology			Multivariable hierarchical logistic regression methodology				
	High- complexity (n = 38)	Low- complexity (n = 51)	Fisher's exact test; p value	High- complexity (n = 38)	Low- complexity (n = 51)	Fisher's exact test p value	Adjusted odds ratio (95% CI) for major postoperative complication	p value
Meet expectation, number (%)	34 (89%)	46 (90%)	0.742	37 (97%)	50 (98%)	0.674	Low vs high complexity: 0.85 (0.67–1.09)	0.108
Exceed expectation, number (%)	2 (5%)	4 (8%)		0	1 (2%)			
Below expectation, number (%)	2 (5%)	1 (2%)		1 (3%)	0			

O/E = observed-to-expected; CI = confidence interval.

Discussion

Identifying facility factors associated with either excessive or low mortality and morbidity rates after hip fracture surgery is a priority of healthcare providers, hospital administrators, and policy makers as such information may reflect overall healthcare quality, focus efforts for improvement, and determine resource allocation. Unlike elective joint arthroplasty, hospital and surgeon volume for hip fracture surgery has not been consistently shown to be associated with mortality [5, 7-10, 21, 24, 27, 30]. The VHA is a single-payer system with facilities that vary in size, number of patients served, and services provided; these are among the factors that determine resource allocation within the VHA, which is closely tied to the VHA facility complexity level designation. We investigated the specific factors of complexity level designation and hip fracture surgical volume and their association, if any, with hip fracture surgery morbidity and mortality. Whether stratified by facility complexity level or hip fracture surgical volume, we observed no differences in the distribution of outlier facilities based on postoperative complications among VHA surgical facilities treating hip fractures. The observations do not support the thinking that, as a group, VHA facilities with the highest complexity level designation (1a) or greater hip fracture surgery volume have fewer major postoperative complications after hip fracture surgery. Taken together with many reports that have failed to demonstrate a consistent association between hip fracture surgical volume and mortality [5, 7, 21, 27], we cannot argue against facilities treating these patients based on historical surgical volume or facility resource availability.

Limitations

VHA Patient Population

The VHA patient population is relatively homogenous compared with nonVHA facilities. Two characteristics illustrate major differences between the population we studied and the populations in reports using nonVHA data [5, 7-10, 21, 24, 27, 30]. The VHA population in this report was predominately male, and more than 20% of the population was younger than 60 years of age. This may limit our finding's external validity. Differences in preoperative comorbid conditions between VHA patients and the general population may also compromise external validity. Nearly a quarter of the VHA population had a diagnosis of severe COPD; sepsis within 2 days before surgery was documented in 1% of the VHA population; and 0.3% of patients were transfused with more than 4 units of packed red blood cells 3 days before surgery.

Veterans within VHA may have private insurance policies, permitting them to receive most of their care outside of the

Table 5. Distribution of facility performance for major postoperative complication among facility hip fracture surgical volume

Facility performance	O/E ratio methodology				Multivariable hierarchical logistic regression methodology					
	High-volume (n = 30)	Medium-volume (n = 29)	Low-volume (n=30)	Fisher's exact test p value	High-volume (n = 30)	Medium-volume (n = 29)	Low-volume (n=30)	Fisher's exact test p value	Adjusted odds ratio (95% CI) for major postoperative complication	p value
Meet expectation, number (%)	28 (93%)	25 (86%)	27 (90%)	0.890	29 (97%)	29 (100%)	29 (97%)	0.999	Low vs high: 0.87 (0.73-1.05)	0.155
Exceed expectation, number (%)	1 (3%)	3 (10%)	2 (7%)		0	0	1 (3%)		Medium vs high: 0.89 (0.79-1.02)	
Below expectation, number (%)	1 (3%)	1 (3%)	1 (3%)		1 (3%)	0	0			

VHA system. Veterans, for example, may have all their primary care at a nonVHA facility but choose to have surgery at a VHA facility because of cost, convenience, or as a result of a specific referral. We cannot dismiss the possibility that the population of veterans with private insurance who only get certain treatments at a VHA facility are demographically different from those who get all their care from a VHA facility.

O/E Ratio Metric

The O/E ratio metric has been used to assess hospital, surgeon, and surgical program performance [11, 12, 31]. Awareness of its limitations guides results interpretation. As with any observation, the variance in hospital performance contains a random component; this random component will contribute more to the variance with smaller sample sizes and event rates [1]. Thus, misclassification of facility performance is more likely for low-volume facilities. Rather than using a single sample, judging hospital performance with longitudinal sampling, especially for low-volume facilities, may be more prudent [4]. The O/E ratio is used to identify performance outlier status, but it does not identify mechanisms responsible for outlier status.

The underlying indirect standardization used to calculate the expected number of events for the O/E ratio corresponds to the following question: "what would happen to a facility's patients if they were treated at an 'average' facility?" In some clinical scenarios (eg, transferring a patient from one facility to another), it is critical to distinguish indirect standardization metrics from direct standardization metrics. Among many possible reasons to transfer a patient is the belief that the odds of a better outcome for the patient are higher if the patient is treated at the receiving facility. Direct comparison of facilities uses direct standardization methods with the underlying question being: "What would happen to the entire population of patients if it were treated at a given facility?" The O/E ratio methodology does not directly compare facilities; rather than interpreting that two "average" performing facilities are equal, a more appropriate interpretation may be that both facilities treat a patient population commensurate with their capabilities.

Dataset Limitations

We included a postoperative rise in creatinine, which may be self-limited as a major postoperative complication because of evidence that even mild postoperative acute kidney injury after orthopaedic surgery is associated with short and long-term mortality [2]. A substantial limitation of the dataset was the lack of a field for postoperative cerebral vascular accident.

Dichotomizing Facility Complexity Level

We categorized facilities as high volume or low volume, and high complexity or low complexity. Facilities within each classification are assuredly not homogenous in facility structure and processes. For sample size considerations and to specifically investigate any advantages of facilities achieving the highest complexity level, we labeled all noncomplexity Level 1a facilities as low complexity. Thus, the low-complexity group included complexity Levels 1b and 1c (both considered high-complexity by the VHA but not as high as 1a), complexity Level 2 (intermediate complexity by the VHA), and complexity Level 3 (standard complexity by the VHA) facilities. From the VHA designation perspective, the interpretation of our observations is that complexity Level 1a facilities do not have a different proportion of outlier facilities than noncomplexity Level 1a facilities. This dataset lacks details on facility characteristics or system factors that may affect postoperative complications and mortality more than surgical volume or complexity level, such as the presence or absence of specific models of care (like a perioperative surgical home or enhanced-recovery pathways).

Association Between Facility Complexity Level and Complications

VHA facilities with the highest complexity level designation do not have a disproportionate number of better-than-expected performance outliers for major postoperative complications compared with lower complexity level facilities. The complexity level designation for VHA facilities is unique. With respect to resource availability, comparing teaching or tertiary care centers with community hospitals may be the best approximation. While Koval et al. [19] did not report a difference in mortality or postoperative complication rates between teaching and nonteaching hospitals treating hip fractures when they explored the National Inpatient Sample database, most studies reported lower mortality with enhanced cost-effectiveness among teaching institutions [18, 26, 32, 34]. To interpret these discrepancies, it is important to note that because high-complexity facilities within the VHA and teaching facilities are likely to have more resource availability than low-complexity and nonteaching facilities, a direct comparison between high-complexity level within VHA and teaching facilities within the community may not be valid.

Association Between Facility Volume and Complications

VHA facilities with higher hip fracture surgical volume do not have a disproportionate number of better-than-expected performance outliers for major postoperative complications compared with lower-volume facilities. Although there are variations in the findings of an association between surgical volume and morbidity and mortality after elective joint replacement [17, 20, 28, 33], the preponderance of evidence suggesting an association between surgical volume and mortality [14, 15, 35], functional metrics [16, 17], revisions [13, 20, 23], and postoperative complications [35] has led to the belief that patients treated at higher-volume institutions have lower morbidity and mortality after elective joint arthroplasty. For hip fracture surgery, the association between surgical volume and mortality is not as well established. Several reports suggest an association between higher volume centers and lower mortality [8, 24]. Many have reported no association [5, 7, 10, 27, 30]. Some observed a higher post-surgical mortality rate in higher volume facilities [9, 21]. Wide variations in surgical volume classification challenge the appropriateness of direct comparisons between studies. When compared with nonVHA facilities included in other reports, almost every VHA facility would be classified as low volume; relative surgical volume homogeneity among VHA facilities may partially explain the observed null result.

Conclusions

Our observations suggest that within VHA facilities that perform hip fracture surgery, performance outlier status is not associated with complexity level designation or hip fracture surgical volume. This may imply that most VHA facilities care for a patient risk profile commensurate with their facility capabilities. However, we caution extrapolating observations derived from VHA data to the general population because as a single-payer system serving a specific patient population, the VHA likely serves a patient population that is more homogenous than that found outside of the VHA. As no model predicting adverse events is perfect, the homogeneity may provide a measure of control for both observed and unobserved patient factors that may confound the association between facility groupings and performance; it may also limit the external validity of observations from VHA data. Future studies should aim to identify consistent performance outliers because this information may help identify processes and characteristics that determine outlier status.

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