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Hospital Experience Predicts Outcomes After High-Risk Geriatric Surgery

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Abstract

Background: Geriatric patients require specialized perioperative care, yet the impact of geriatric surgery proportion (a measure of experience) and geriatric surgery volume, on clinical outcomes is unknown. This study analyzes the association between proportion and volume and clinical outcomes after high-risk geriatric surgery.

Methods: Using the 2014 National Inpatient Sample, hospital encounters for older adults (≥65 years) undergoing high-risk geriatric surgery were identified. Geriatric surgery volume was defined as a hospital's annual volume of geriatric patients undergoing high-risk geriatric surgery. Geriatric surgery proportion was calculated as volume divided by the sum of high-risk surgeries in all ages. Hierarchical multivariable regression models identified predictors of inpatient mortality, postoperative length of stay (LOS), and discharge to nursing facility.

Results: There were an estimated 514,950 hospital encounters for older adults undergoing high-risk geriatric surgery from 3,115 hospitals. Mean proportion was 0.53±0.19; median volume was 60 cases/year, ranging from 5 to 3,235. After adjustment, comparing the 90th to 10th percentiles, higher proportion was associated with decreased mortality (odds ratio (95% CI) 0.81 (0.73-0.88); $p<0.001$) and shorter postoperative LOS (−4.44% (−5.49-3.39%); $p<0.0001$). Higher volume was not associated with mortality but was associated with longer LOS (7.76% (6.75-8.77%); $p<0.0001$) and decreased discharge to nursing facility (0.87 (0.79-0.95); $p=0.003$).

Conclusions: Treatment of geriatric patients at hospitals with the highest proportion of high-risk geriatric surgery, or the most experience, is associated with improved outcomes. High-proportion hospitals should be examined to understand the mechanisms by which better quality geriatric

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surgical care is achieved, while lower-proportion hospitals may be targets for quality improvement efforts.

Introduction

The United States population is aging, and the number of older adults undergoing surgery will continue to increase.[1,2] Older patients are at higher risk for poor outcomes after surgery and require specialized perioperative care. The American College of Surgeons Coalition for Quality in Geriatric Surgery[3] has identified valid and feasible hospital-level standards as part of a verification and quality improvement program for geriatric surgery.[4] Hospital-level factors that may contribute to quality of care include hospital characteristics, resources, or systems in place for the delivery of patient care. An example of a hospital characteristic is a hospital's procedural volume; an example of a hospital resource is the presence of patient-navigators to assist patients throughout the perioperative process; an example of a hospital system is a multidisciplinary preoperative conference to discuss high-risk older adults. While provider-level factors such as individual provider knowledge, experience, or practice patterns are important, much of the quality of care in geriatric surgery may be driven by hospital-level factors.

Studies in surgical subspecialties including surgical oncology, trauma, and bariatric surgery have shown that hospitals performing high volumes of procedures have better outcomes.[5-8] The literature on geriatric surgery has also begun to explore the importance of hospital proportion, given that quality of care may be more dependent on hospital-level processes of care rather than individual surgeon or operative technique.[9-11] However, studies on the association of both proportion and volume with outcomes in geriatric surgical patients have been limited to isolated regions or specific surgical subspecialties and have found conflicting results.[9,10] Multi-specialty studies are needed to determine the relationships between geriatric surgery proportion and volume and outcomes.

This study utilizes a large national database to analyze the association of hospital characteristics, including both geriatric surgery proportion and volume, with clinical outcomes after high-risk geriatric surgery. Our primary outcome was inpatient mortality, and secondary outcomes were postoperative length of stay (LOS), and discharge to nursing facility. While traditionally, the importance of surgical volume has been emphasized, consider an example of two hospitals, Hospital A and Hospital B, where proportion may be a better measure of "experience" in the context of geriatric surgery. Hospital A has a total surgical volume of 100,000 operations per year, 500 of which are geriatric surgery operations (and 99,500 of which are on younger adults). Hospital B has a total surgical volume of 1,000 operations per year, 500 of which are geriatric surgery operations. Thus, Hospital A has a volume of 500 and a proportion of 0.005 whereas Hospital B has a volume of 500 and a proportion of 0.5. The surgical staff at Hospital A are accustomed to caring for surgical patients, but only a small proportion of those surgical patients are older adults, so staff may not specifically tailor their care to older adults. On the other hand, surgical staff at Hospital B care for fewer surgical patients every year, but one out of every two patients they care for is an older adult and thus each surgical team member has more experience caring for older adults undergoing surgery. So in summary, a hospital treating a higher proportion of geriatric surgery patients may be more inclined to focus on the nuanced care of this vulnerable population since these patients make up a greater percentage of their overall surgical volume. On the other hand, a hospital with a high volume of geriatric surgery may also treat a high volume of younger adult surgical patients and therefore may not dedicate unique resources specifically to the care of geriatric patients. Thus, we postulated that proportion, a measure of experience, matters more than volume in the case of geriatric surgery. Specifically, we hypothesized that hospitals with a higher proportion of high-risk geriatric surgery have better patient outcomes, regardless of high-risk geriatric surgery volume.

Methods

Data Source and Study Population:

The data source was the 2014 National Inpatient Sample (NIS) as provided by the Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality.[12] The NIS approximates a 20% stratified sample of discharges from United States hospitals, represents more than 96% of the United States population, and is the largest publicly available all-payer inpatient database.

Hospital encounters were identified using ICD-9 procedure codes that have previously been defined as high-risk in the geriatric population. Using a modified Delphi approach, Schwarze et al[13] identified a list of 227 operations associated with a ≥1% inpatient mortality in patients ≥65 years. This list includes major inpatient operations across a wide range of subspecialties (e.g., brain lobectomy, pneumonectomy, coronary artery bypass graft, lower limb endarterectomy, splenectomy, colectomy, kidney transplant), but does not include lower-risk operations common in the geriatric population (e.g., total hip arthroplasty, prostatectomy, mastectomy, cholecystectomy). The sample was limited to geriatric patients, defined as age 65 years and older, and to hospitals that performed at least one high-risk geriatric operation.

Patient, Case, and Hospital Characteristics:

Patient variables included age (0 – 90 years, with ages over 89 aggregated into a single category of 90 years or older), race/ethnicity (White; Black; Hispanic; Asian or Pacific Islander; Native American; other), sex (female; male), primary payer (Medicare; Medicaid; private insurance; uninsured; other), and Charlson comorbidity index with Deyo modification (CCI).[15] The CCI is calculated using seventeen comorbidities with different weights (e.g., diabetes is 1 point, while metastatic solid tumor is 6 points), and is a validated measure to predict the risk of mortality.[14,15]

Case variables included admission status (elective; non-elective) and surgical subspecialty (cardiac; vascular; colorectal; general; urological; thoracic; transplant; neurological; orthopedic). Cases were assigned to surgical subspecialties based upon a modified Clinical Classifications Software description, originally provided by HCUP and adapted by Schwarze et al.[13,16,17] If a hospital encounter included more than one high-risk geriatric operation, the operation that occurred earliest in the admission was assigned as the index procedure.

Hospital variables included size (small; medium; large), location (rural; urban), teaching status (teaching; non-teaching), and ownership (government, non-federal; private, non-profit; private, investor-owned). Hospital size is determined based on the number of hospital beds as well as location, teaching status, and region of the United States. A hospital is designated as a teaching hospital if it has an Accreditation Council for Graduate Medical Education-approved residency program, if it is a member of the Council of Teaching Hospitals, or if it has a ratio of full-time equivalent interns and residents to beds of 0.25 or higher.

Primary predictors of interest were hospital geriatric surgery volume (hereafter referred to as volume) and hospital geriatric surgery proportion (hereafter referred to as proportion), which were both continuous variables. Volume was simply the weighted number of high-risk geriatric operations performed at that hospital in 2014. Proportion was calculated as volume divided by the sum of all high-risk operations performed in patients of any age, with a theoretical range of 0 to 1.

Outcomes:

Our primary outcome was inpatient mortality, and secondary outcomes were postoperative length of stay (in days), and discharge to nursing facility. For encounters with more than one high-risk geriatric operation, the postoperative LOS was calculated from the date of the index procedure. Discharge to nursing facility was defined as discharge to skilled nursing facility, intermediate care or other type of facility, not including transfer to short term hospital. Postoperative LOS and discharge to nursing facility analyses included only patients that survived to discharge.

Statistical Analysis:

Univariate data included proportions (categorical data), means ± standard deviations (normally distributed continuous variables), and medians with ranges (non-normally distributed continuous variables). All estimates and statistics were adjusted using sampling weights and stratification as well as sample clustering within hospital.[18] The standard error estimates are based upon weighting, stratification and clustering and reflect the uncertainty of the values as national estimates.

Unadjusted inpatient mortality, postoperative LOS, and discharge to nursing facility were estimated for each decile of proportion and volume and plotted against the median of the decile. Hierarchical multivariable regression models were fitted to identify hospital characteristics predictive of inpatient mortality (logistic), postoperative LOS (linear with log link), and discharge to nursing facility (logistic). For continuous predictors of interest (proportion and volume), we calculated odds ratios by comparing the 90th percentile to the 10th percentile. This method excludes the influence of extreme outliers and is in lieu of creating categorical variables. Hospital identifiers were included as a random effect to account for clustering of patients within hospitals. All models were adjusted for patient sociodemographic and case characteristics including age, race/ethnicity, sex, primary payer, CCI, admission elective status, and surgical subspecialty.

We performed a sensitivity analysis to determine if the same relationships were observed for patients at hospitals above the lowest decile of volume, given that proportion has high variance in the lowest volume decile. We also performed a sensitivity analysis to determine if the same relationships were observed for patients at hospitals above the lowest decile of proportion, given that our unadjusted results suggested that the lowest decile of proportion may have higher inpatient mortality than the other deciles.

Statistical analyses were completed using SAS v9.4 (SAS Institute, Cary, NC) and Stata v14.0 (StataCorp, College Station, TX). Two-sided p-values less than 0.05 were considered significant. Data analysis was concordant with all Agency for Healthcare Research and Quality standards.[12,19] This study was deemed exempt by the Institutional Review Board at the University of California, Los Angeles.

Results

Patient and Hospital Characteristics:

Over 1 million high-risk surgeries were performed in 2014, of which 46.7%, or 514,950, were performed in geriatric patients. Most patients undergoing high-risk geriatric surgery were white (81.1%), male (56.7%), and had Medicare as the primary payer (87.8%) (Table 1). The mean age of patients undergoing high-risk geriatric surgery was 74.4 years, and 43.4% had a CCI ≥ 3. More than half of the admissions were elective (55.3%), and the most common surgical subspecialty was cardiac (32.7%), followed by vascular (20.6%) and colorectal (18.6%).

Of 4,411 hospitals participating in in HCUP, 3,115 hospitals performed at least one high-risk geriatric operation in 2014 (Table 2). Examining the hospital-level data, the mean proportion was 0.53 and standard deviation 0.19. The median volume was 60 cases, with a range of 5 – 3,235. There were approximately equal numbers of small, medium, and large hospitals. Urban, teaching hospitals were most common (39.0%), followed by urban, non-teaching hospitals (35.5%) and rural hospitals (25.5%). The majority of hospitals were private, non-profit (68.8%). Mean proportion and median volume varied based upon hospital size, location/teaching status and ownership. For example, examining all rural hospitals (n = 795), the mean proportion was 0.61 ± 0.24 and median volume was 15, whereas when examining all urban teaching hospitals (n = 1,215), the mean proportion was 0.47 ± 0.15 and median volume 195 (Table 2).

Unadjusted Outcomes:

For our primary outcome, we found an overall inpatient mortality rate of 4.6%. Mortality rates appeared lower with both greater proportion (Fig 1a) and volume (Fig 1b). For secondary outcomes, results were mixed. Median postoperative LOS was 5.4 days and appeared shorter with greater proportion (Fig 1c) but longer with higher volume (Fig 1d). Rate of discharge to nursing facility was 28.8% and appeared higher with greater proportion (Fig 1e) but lower with higher volume (Fig 1f).

Multivariable Analyses:

On multivariable analyses, greater proportion was associated with lower mortality (adjusted odds ratio for 90^{th} vs. 10^{th} percentile (aOR) 0.81; 95% confidence interval (CI) 0.73 – 0.88;

p<0.0001) but volume was not (aOR 0.92; CI 0.80-1.05; p=0.219), after adjusting for patient and hospital characteristics (Table 3). Adjusted mortality rate for patients in the highest proportion decile was 4.0%, compared to 5.3% in the lowest decile.

Similar to the unadjusted analysis, both proportion and volume were associated with postoperative LOS after adjusting for patient and hospital characteristics, but the direction of the effect was opposite. Greater proportion was associated with shorter postoperative LOS (median percent change for 90^{th} vs. 10^{th} percentile −4.4%; CI −3.4 to −5.5%; p<0.0001). This −4.4% change means that the difference in postoperative LOS when comparing high proportion and low proportion hospitals depends on the length of stay itself. For example, at a median postoperative LOS of 7 days, hospitals at the 90^{th} percentile of proportion are associated with a 4.4% shorter postoperative LOS compared to hospitals at the 10^{th} percentile of proportion, or 0.3 days. At a higher median postoperative LOS of, for example, 30 days, there is a larger difference of 1.3 days. The median adjusted postoperative LOS for patients at hospitals in the highest decile of proportion was 5.7 days, compared to 6.1 days for patients at hospitals in the lowest decile of proportion. However, higher volume was associated with longer postoperative LOS (median percent change for 90^{th} vs. 10^{th} percentile 7.8%; CI 6.8% – 8.8%; p<0.0001). Again, this 7.8% change means that the difference in postoperative LOS when comparing high proportion and low proportion hospitals depends on the length of stay itself. In this case, at a median postoperative LOS of 7 days, hospitals at the 90^{th} percentile of volume are associated with a 7.8% longer postoperative LOS compared to hospitals at the 10^{th} percentile of volume, or 0.6 days. At a higher median postoperative LOS of, for example, 30 days, there is a larger difference of 2.3 days. The median adjusted postoperative LOS for patients at hospitals in the highest decile of volume was 6.4 days, compared to 5.7 days for patients at hospitals in the lowest decile of volume.

After adjusting for patient and hospital characteristics, proportion was not significantly associated with discharge to nursing facility (aOR 1.07; CI 1.00 – 1.15; p=0.051) but higher volume was associated with lower odds of discharge to a nursing facility (aOR 0.87; CI 0.79 – 0.95; p=0.003). Patients at hospitals in the highest decile of volume were discharged to a nursing facility at a rate of 26.5%, compared to 30.2% in patients at hospitals in the lowest decile.

Sensitivity Analyses:

When models were repeated on a subset of the sample excluding hospitals in the lowest decile of volume (Supplementary Table S1), and excluding hospitals in the lowest decile of proportion (Supplementary Table S2), results were generally the same.

Discussion

Older adults are at greater risk for poor outcomes after surgery than their younger adult counterparts. Yet, with the aging of the population, an increasing number of older adults will require surgery. As programs are implemented to improve the quality of care for this vulnerable population, we must better understand the hospital-level factors that contribute to quality care in geriatric surgery.

This contemporary national analysis demonstrates that treatment at hospitals with the highest proportion is associated with improved outcomes in older adult patients after high-risk geriatric surgery. Among hospitals with the same volume, those with the highest proportion had significantly lower inpatient mortality and shorter postoperative LOS. Volume had no impact on inpatient mortality and in fact was associated with longer postoperative LOS. However, the highest volume was associated with a lower rate of discharge to nursing facility. These relationships were maintained in sensitivity analyses where only hospitals above the lowest decile of volume and only hospitals above the lowest decile of proportion were analyzed.

This study's findings are in contrast with the existing literature on volume-outcome relationships in surgery. One reason for this may be that many studies that find higher volume to be a predictor of improved outcomes examine hospital volume alone and do not include proportion as a predictor in their models.[5-8] Two examples from the geriatric trauma literature support this explanation. One study using the Pennsylvania Trauma Outcome Study Database only examined volume and found that higher geriatric trauma volume was significantly associated with reduced mortality,[11] while another study using the California State Inpatient Database included both volume and proportion as predictors and their results were similar to ours, with proportion as the main driver of improved outcomes.[9]

Another reason why our volume-outcome findings are inconsistent with other studies may be that unique processes of care are at play for geriatric patients compared to younger adult surgical patients. We found that higher volume was associated with longer postoperative LOS, which is in contrast to studies of complex surgical procedures showing that higher hospital volume is associated with shorter postoperative LOS.[20,21] While longer postoperative LOS is undesirable, holding all else equal, longer postoperative LOS may be acceptable if it results in improved other outcomes. For example, we found that higher volume was a significant predictor of reduced discharge to nursing facility. One possible explanation is that these hospitals are taking the time to adequately prepare patients for home discharge by setting up home health services or using aggressive inpatient physical therapy to try to maintain function and mobility. Given that discharge disposition is a patient-centered quality measure, and studies have shown improved recovery and survival in patients that are discharged home after surgery, a tradeoff of slightly longer postoperative LOS for reduced discharge to nursing facility may be appropriate in this geriatric population.[22] Of note, this study's finding that greater proportion is associated with shorter postoperative LOS but has no effect on discharge disposition suggests that high proportion hospitals have the resources to reduce postoperative LOS without the tradeoff of discharging more patients to nursing facilities (e.g., protocols for early mobilization that prevent functional decline). These results illustrate that while the goal should be for all hospitals to function like high-proportion hospitals (e.g., minimizing postoperative LOS without discharging more patients to nursing facilities) there are nuances to consider when caring for older patients. With the movement toward patient-centered, value-based care, minimizing discharges to a nursing facility (which are both expensive and not usually desired by the patient whose goal is to return to prior living situation) may become more important to hospital systems, even if this means a slightly longer postoperative LOS.

The findings from this study suggest that hospitals with the highest proportion may be equipped with better resources to provide high-quality care to older adults. The nuances in providing care for geriatric patients are not routinely taught during surgical training, and clinical practice guidelines for perioperative care of the older adult are relatively new,[23,24] suggesting it may be provider experience as a result of greater hospital proportion that leads to improved perioperative care. Alternatively, hospitals with greater proportion may invest in systems to ensure high-quality care for geriatric surgery patients. Several studies across multiple surgical subspecialties have shown that specialized care for geriatric patients, including dedicated geriatric wards, co-management with a geriatrics team, or routine geriatric consultation leads to better outcomes.[25-27] Some have advocated for the creation of Geriatric Surgery Institutes, which would provide specialized care to this vulnerable population.[28]

There are several limitations to this study. While we postulate that greater proportion is indicative of superior processes of care, we cannot determine the precise mechanism of the relationship between greater proportion and improved outcomes. We were not able to include surgeon volume in our model to determine the effect of the provider, as other studies have done[10,29,30] and we do not have information about the geriatric-specific services provided at the hospitals included in our dataset. The NIS lacks clinical detail and thus we were unable to determine risk-assessment characteristics important in older adults such as frailty, functional status, or history of cognitive dysfunction. Additionally, the NIS does not provide information on long-term outcomes or length of stay at nursing facilities. Despite these limitations, the NIS remains a nationally representative database and thus the results from this study are generalizable to hospitals performing high-risk geriatric surgery across the United States.

Older patients require specialized perioperative care and it is important to understand the hospital-level factors associated with high-quality care in geriatric surgery. This study found that hospitals with the greatest proportion of high-risk geriatric surgery had reduced inpatient mortality and shorter postoperative LOS compared hospitals with the lowest proportion. In contrast to other studies, it found that the absolute volume of high-risk geriatric surgery performed is not associated with inpatient mortality, but is associated with longer postoperative LOS, as well as decreased discharge to nursing facility. Hospital proportion of surgery is an important and under-studied hospital characteristic that should be included in future models of hospital-level characteristics and outcomes. Future studies should include granular information about hospitals' geriatric-specific processes of care to elucidate the mechanisms underlying the proportion-outcome relationship after surgery in older adults. Furthermore, high-proportion hospitals that have more experience in geriatric surgery may be particularly poised to teach surgical residents about the nuances of caring for older adults undergoing surgery (e.g., medication management including the issue of polypharmacy, nutritional optimization, and delirium prevention protocols). This study is an important step toward developing programs to enable hospitals across the United States to provide high-quality surgical care to the rapidly aging population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

LOS	Length of stay
NIS	National Inpatient Sample
HCUP	Healthcare Cost and Utilization Project
CCI	Charlson comorbidity index
aOR	Adjusted odds ratio

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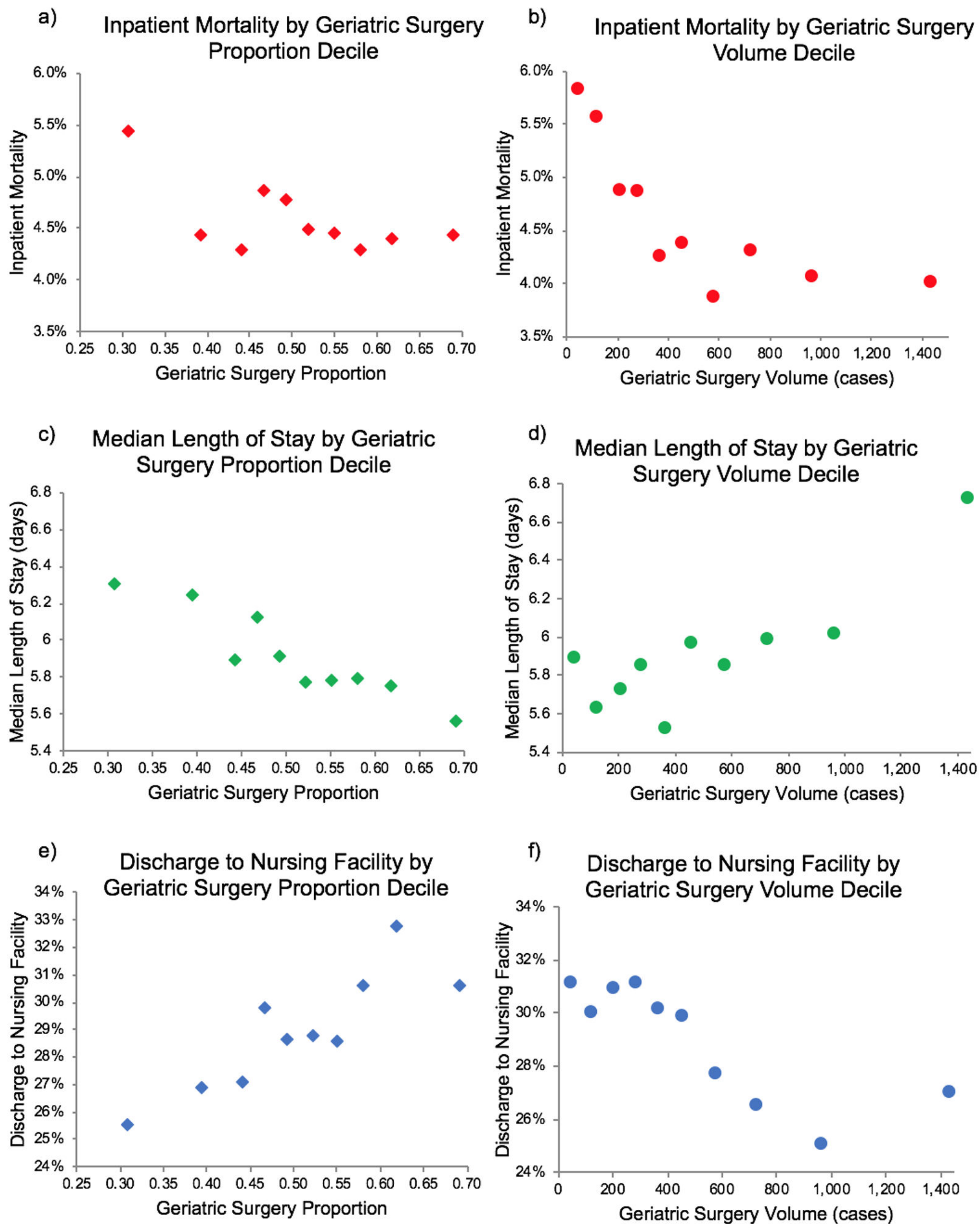

Figure 1.

Unadjusted inpatient mortality, median length of stay, and discharge to nursing facility by decile of geriatric surgery proportion and volume. Outcomes are calculated as the overall value within each decile, then plotted against the median of each decile. For example, the first decile of geriatric surgery proportion is 0.01 to 0.36 and the median is 0.31. The inpatient mortality within this decile is 5.44%. Thus, the corresponding point in panel (a) is (0.31, 5.44).

Table 1:

Patient and Case Characteristics of Study Population

Characteristics	Unweighted n = 102,990 Weighted n = 514,950	
	Value	**Standard Error**
Age, years (mean)	74.4	0.04
Male (%)	56.7	0.21
Primary Payer (%)		
Medicare	87.8	0.31
Medicaid	1.1	0.06
Private	9.7	0.30
Uninsured	0.5	0.04
Other	1.0	0.07
Race/ethnicity (%)		
White	81.1	0.49
Black	7.7	0.24
Hispanic	6.0	0.31
Asian or PI	2.2	0.16
Native American	0.4	0.05
Other	2.5	0.19
Charlson Comorbidity Index (%)		
0	14.0	0.15
1	20.2	0.17
2	22.4	0.14
≥ 3	43.4	0.26
Elective Admission (%)	55.3	0.45
Surgical Specialty (%)		
Cardiac	32.7	0.49
Vascular	20.6	0.25
Colorectal	18.6	0.26
General	15.9	0.22
Urological	6.0	0.15
Thoracic	4.8	0.10
Transplant	1.0	0.09
Neurological	0.3	0.02
Orthopedic	0.0	0.01

Note: all proportions are based on non-missing data. Standard errors are based upon weighting, stratification and clustering and reflect the uncertainty of these values as national estimates.

Table 2:

Geriatric Surgery Proportion and Volume by Hospital Characteristic

Characteristics	No. (%)	Geriatric Surgery Proportion	Geriatric Surgery Volume
		(mean ± SD)	(median [range])
Overall	3,115 (100)	0.53 ± 0.19	60 [5-3,235]
Hospital Size			
Small	1,088 (34.9)	0.57 ± 0.24	25 [5-770]
Medium	986 (31.7)	0.51 ± 0.17	68 [5-1,375]
Large	1,041 (33.4)	0.51 ± 0.15	175 [5-3,235]
Location/Teaching Status			
Rural	795 (25.5)	0.61 ± 0.24	15 [5-1,165]
Urban, non-teaching	1,105 (35.5)	0.54 ± 0.18	55 [5-1,000]
Urban, teaching	1,215 (39.0)	0.47 ± 0.15	195 [5-3,235]
Hospital Ownership			
Government, Non-Federal	412 (13.2)	0.53 ± 0.24	30 [5-1,995]
Private, Non-Profit	2,143 (68.8)	0.54 ± 0.18	70 [5-3,235]
Private, Investor-Owned	560 (18.0)	0.52 ± 0.19	60 [5-1,405]

SD = standard deviation

Table 3:

Multivariable Analysis of Factors Associated with Inpatient Mortality, Postoperative Length of Stay, and Discharge to Nursing Facility in Geriatric Patients Undergoing High-Risk Geriatric Surgery

		Inpatient mortality (adjusted odds ratio; 95% CI)	Postoperative length of stay (mean % change[†]; 95% CI)	Discharge to nursing facility (adjusted odds ratio; 95% CI)
Hospital geriatric surgery proportion - 90th percentile vs. 10th percentile		0.81 (0.73-0.88) ***	−4.44 (−5.49- −3.39) ***	1.07 (1.00-1.15)
Hospital geriatric surgery volume - 90th percentile vs. 10th percentile		0.92 (0.80-1.05)	7.76 (6.75-8.77) ***	0.87 (0.79-0.95) **
Hospital size	Small	Reference		
	Medium	1.10 (0.98-1.24)	2.56 (1.23-3.89) ***	1.01 (0.93-1.10)
	Large	1.16 (1.02-1.33) *	4.76 (3.45-6.07) ***	1.05 (0.96-1.15)
Hospital location / Teaching status	Rural	Reference		
	Urban, non-teaching	1.08 (0.92-1.27)	4.32 (2.80-5.84) ***	1.16 (1.03-1.30) *
	Urban, teaching	1.14 (0.95-1.36)	7.70 (6.06-9.35) ***	1.23 (1.09-1.38) ***
Hospital ownership	Government, non-federal	Reference		
	Private, non-profit	0.95 (0.83-1.08)	−2.63 (−4.00- −1.26) ***	1.05 (0.96-1.15)
	Private, investor-owned	1.05 (0.90-1.22)	−0.67 (−2.02-0.68)	1.15 (1.04-1.29) **
Age		** ‡	** ‡	1.081 (1.079-1.084) ***
Age squared		* ‡	* ‡	N/A
Female		1.03 (0.96-1.10)	2.80 (2.26-3.35) ***	1.54 (1.49-1.59) ***
Race/ethnicity	White	Reference		
	Black	0.90 (0.80-1.01)	7.73 (6.58-8.88) ***	1.33 (1.25-1.41) ***
	Hispanic	0.96 (0.84-1.09)	−0.60 (−1.45-0.25)	0.85 (0.76-0.95) **
	Asian/Pacific Islander	0.88 (0.70-1.09)	−1.51 (−2.77- −0.25) *	0.61 (0.53-0.69) ***
	Native American	0.90 (0.56-1.43)	−7.00 (−9.94- −4.07) ***	0.81 (0.58-1.14)
	Other	1.02 (0.85-1.24)	4.61 (2.45-6.76) ***	1.05 (0.94-1.17)
CCI		1.12 (1.11-1.14) ***	*** §	1.12 (1.11-1.13) ***
CCI squared		N/A	*** §	N/A
Primary payer	Medicare	Reference		
	Medicaid	1.15 (0.88-1.51)	3.07 (0.83-5.31) **	0.66 (0.54-0.80) ***
	Private/HMO	0.93 (0.82-1.05)	0.31 (−0.51-1.13)	0.73 (0.68-0.78) ***
	Self-pay	1.48 (1.01-2.17) *	3.03 (−0.17-6.22)	0.44 (0.32-0.61)
	No charge	2.50 (1.02-6.16) *	10.70 (1.99-19.41) *	0.28 (0.11-0.68) **
	Other	1.08 (0.79-1.48)	2.22 (0.23-4.22) *	0.72 (0.59-0.87) ***
Elective operation		0.30 (0.28-0.33) ***	−23.45 (−24.06- −22.84) ***	0.39 (0.37-0.40) ***

		Inpatient mortality (adjusted odds ratio; 95% CI)	Postoperative length of stay (mean % change†; 95% CI)	Discharge to nursing facility (adjusted odds ratio; 95% CI)
Surgical subspecialty type	General surgery	Reference		
	Cardiac surgery	0.61 (0.55-0.67)***	0.61 (−0.35-1.57)	1.72 (1.61-1.84)***
	Colorectal surgery	0.87 (0.79-0.95)**	3.38 (2.55-4.22)***	1.11 (1.06-1.18)***
	Neurosurgery	0.78 (0.48-1.26)	−54.36 (−59.29- −49.43)***	1.08 (0.82-1.42)
	Orthopedic surgery	1.17 (0.25-5.45)	15.52 (2.42-28.63)*	11.21 (4.10-30.64)***
	Thoracic surgery	0.46 (0.39-0.55)***	−49.45 (−51.67- −47.24)***	0.71 (0.65-0.78)***
	Transplant surgery	0.44 (0.31-0.63)***	−4.24 (−8.68-0.19)	0.54 (0.42-0.71)***
	Urologic surgery	0.34 (0.28-0.43)***	−25.86 (−27.18- −24.53)***	0.76 (0.70-0.83)***
	Vascular surgery	0.69 (0.62-0.76)***	−52.83 (−54.02- −51.65)***	1.12 (1.05-1.19)***

CCI = Charlson comorbidity index, HMO = health maintenance organization

P-value

*<0.05

**<0.01

***<0.001

†Negative values indicate decreased postoperative length of stay. For example, if mean length of stay was 7 days then length of stay would decrease by 4.44% or 0.31 days

‡In the models for inpatient mortality and postoperative length of stay, age is a significant predictor, but not on a linear scale, so there is no single odds ratio for age or age squared. The log odds = C + B1(age) − B2(age squared) where C depends on the other variables in the model. Neither the log odds nor the odds is a constant rate since mortality and postoperative length of stay are not a linear function of age.

§In the model for postoperative length of stay, CCI is a significant predictor, but not on a linear scale, so there is no single odds ratio for CCI or CCI squared. The log odds = C + B1(CCI) − B2(CCI squared) where C depends on the other variables in the model. Neither the log odds nor the odds is a constant rate since postoperative length of stay is not a linear function of CCI.