Emergency general surgery in geriatric patients: A statewide analysis of surgeon and hospital volume with outcomes

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BACKGROUND: Geriatric patients undergoing emergency general surgery (EGS) face significant morbidity and mortality. We assessed how surgeon and hospital volumes affected these outcomes.

METHODS: We identified patients at least 65 years old in Maryland's Health Services Cost Review Commission database from 2012 to 2014 who underwent one of 12 EGS procedures, as defined by the American Association for the Surgery of Trauma, and then calculated four outcomes: mortality rate, the incidence of at least one of eight common in-hospital EGS complications, failure-to-rescue (death after experiencing a postoperative complication), and the 30-day readmission rate. Median annual volumes of geriatric-EGS procedures divided both surgeons and hospitals into two groups (low volume and high volume). Multivariable logistic regressions calculated associations between the volume groups and outcomes after adjusting for patient, surgeon, and hospital factors, and hospital clusters.

RESULTS: We identified 3,832 patients who had an EGS procedure by 302 surgeons (median: 8 geriatric-EGS/year, IQR: 3–18) at 44 hospitals (median: 82 geriatric-EGS/year, IQR: 35–132). While operating on 16.5% of all geriatric-EGS patients, low-volume surgeons had higher risk-adjusted adverse outcomes: mortality (7.0% vs. 4.0%, $p = 0.005$), in-hospital complications (22.1% vs. 19.7%, $p = 0.13$), failure-to-rescue (17.3% vs. 12.1%, $p = 0.021$), and 30-day readmissions (11.2% vs. 10.0%, $p = 0.55$). After adjustment, low-volume surgeons were associated with higher mortality (adjusted odds ratio [aOR] 1.86, 95% CI [1.21–2.86]) and failure-to-rescue rates (aOR 1.74 [1.09–2.80]) but not in-hospital complications (aOR 1.20 [0.95–1.51]) or 30-day readmissions (aOR 1.07 [0.85–1.34]). In contrast, low-volume hospitals relative to high-volume hospitals, and hospitals serving lower proportions of geriatric-EGS patients, were not associated with adverse outcomes.

CONCLUSION: Relative to their higher-volume counterparts, surgeons performing eight or fewer geriatric-EGS procedures annually were associated with an 86% higher odds of death and 74% higher odds of failure-to-rescue in this elderly EGS patient population. These findings underscore the need for focused care of elderly surgical patients. (*J Trauma Acute Care Surg.* 2018;84: 864–875. Copyright © 2018 American Association for the Surgery of Trauma. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic and epidemiological, level IV.

KEY WORDS: Emergency general surgery; geriatrics; volume; outcomes; surgeon volume.

Medical advances have led to an increase in life expectancy in developed countries.[1] Currently, in the USA, the 15% of the population that is 65 years of age or older is projected to rise to 25% by the year 2060.[2,3] Additionally, the geriatric population disproportionally accounts for 40% of all inpatient discharges[4] and 38% of the 51 million procedures performed annually in the USA.[3–5] Surgeons must gain a better understanding of the pathophysiology inherent of elderly patients that distinctively affects their perioperative care.

Much of the surgical literature focuses on geriatric trauma and elective geriatric surgery,[6–9] and more recent studies have begun identifying risk factors associated with emergency general surgery (EGS) outcomes in the elderly.[10–12] However, there is a paucity of data investigating the contemporary association between volume and EGS outcomes, especially in the elderly. We used a statewide database to characterize EGS outcomes among the geriatric population as well as to determine their associations with both surgeon and hospital annual geriatric-EGS volumes. We hypothesized that although the geriatric patient population undergoing EGS procedures would experience high mortality, complication, failure-to-rescue, and 30-day readmission rates, lower volume surgeons but not lower volume hospitals would be associated with adverse outcomes.

METHODS

Database and Procedures

The Maryland Health Services Cost Review Commission database[13] captures all surgical patients within the state's hospitals, including those who undergo same-day outpatient surgery and those admitted to the hospital. We queried this database for selected EGS procedures from July 1, 2012 to September 30, 2014. We identified each surgeon's primary reported specialty and hospital characteristics from Medicare's Physician Compare database[14] and the American Hospital Association,[15] respectively.

The American Association for the Surgery of Trauma has defined criteria for identifying EGS procedures using International Classification of Diseases-9-Schedule Modification codes.[16] Using these criteria, we analyzed 12 EGS procedures, of which seven have previously been found to account for 80% of the national burden of operative EGS in the USA; the remaining five occurred with the greatest frequency thereafter.[17] These procedures included an appendectomy (ICD-9-CM 47.0x), a cholecystectomy (51.2x), an open large intestine excision (45.7x), a small intestine excision (45.6x), a peritoneal adhesiolysis (54.5x), a control of stomach or duodenum ulcer

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and hemorrhage (44.4x), an exploratory laparotomy (54.1x), an umbilical hernia repair (53.4x), a unilateral inguinal hernia repair (53.0x), an anterior abdominal wall hernia repair (53.6x), an excision of lesion, skin, or subcutaneous tissue (86.2x), and a perirectal tissue incision or excision (48.8x).

Study Population and Patient, Surgeon, and Hospital Characteristics

The dataset consisted of patients 65 years or older with one of the above ICD-9-CM procedure codes who were admitted urgently or emergently, or who were admitted through the emergency department if the admission type was unknown. We excluded procedures not performed by general surgeons, not performed on day 0 or 1 of admission, and those associated with trauma (ICD-9-CM diagnosis codes 800.x to 950.x), as previously described.[18]

We collected the following patient factors a priori and divided them into the following categorical groups: gender (male; female), race and ethnicity (white; black; Hispanic; other/missing), age (65–74; 75–84; 85+), Elixhauser score[19] (0–1; 2–4; 5+) to capture acute and chronic comorbidities that have been shown to be significantly associated with in-hospital mortality, and payer (private; Medicare; Medicaid; self-pay). As a surrogate marker of experience, we used a threshold of 15 years since medical school graduation (≤15 years; >15 years) to identify surgeons who are in practice and operating after finishing residency and fellowship training. Hospital characteristics included number of beds (≤200; 201–400; >400), region (urban; rural), and affiliation (teaching; non-teaching).

Volume Categories and Outcomes

We used median annual volumes of EGS procedures in geriatric patients to create categories for both surgeons (low-volume: ≤8 geriatric-EGS/year; high-volume: >8/year) and hospitals (low-volume: ≤82 geriatric-EGS/year; high-volume: >82/year). As there are no objective guidelines for creating surgeon or hospital volume thresholds, we believed that using median volumes would be appropriate for investigating an association between volume and outcomes. In our sensitivity analyses, we used the median annual volume of all EGS procedures among patients at least 20 years of age to recreate volume categories for both surgeons (low-volume: ≤24 all EGS/year; high-volume: >24/year) and hospitals (low-volume: ≤308 all EGS/year; high-volume: >308/year).

The four outcomes we evaluated were in-hospital mortality, the presence of at least one of eight common in-hospital EGS complications,[20] failure-to-rescue, and 30-day inpatient readmissions. We identified mortality when the disposition at discharge was "expired" and used previously published ICD-9-CM codes[20] to identify the following complications: acute renal failure, pulmonary failure, surgical site infection (SSI), gastrointestinal bleed, pneumonia, hemorrhage, myocardial infarction, and deep vein thrombosis/pulmonary embolism (DVT/PE). Rates of failure-to-rescue were defined as the proportion of patients who died among those who experienced a postoperative complication. Readmissions were identified from the unplanned 30-day readmission variable, which captured unplanned admissions to any hospital in the state.

Statistical Analysis

We used χ^2 tests to evaluate unadjusted differences in patient and hospital characteristics between low-volume and high-volume surgeons, and then calculated mortality, complication, failure-to-rescue, and 30-day readmission rates among all procedures and for individual procedures. We then described the distribution of annual geriatric-EGS volumes for surgeons and hospitals by the median and interquartile range (IQR, 25th–75th).

Using multivariable logistic regressions and post-estimation, we first calculated the risk-adjusted mortality, in-hospital complications, failure-to-rescue, and 30-day readmissions rate for both low geriatric-EGS volume and high geriatric-EGS volume surgeons. Next, we performed additional multivariable logistic regressions to calculate associations between both surgeon and hospital volume categories with each of the four outcomes. We evaluated these models using the Hosmer–Lemeshow test and by calculating area under the receiver operating characteristic curve (AUC). We then performed several sensitivity analyses. First, we repeated the previous four regressions using new surgeon and hospital volume categories created from among all adult patients undergoing EGS procedures (at least 20 years of age) and also evaluated outcomes only among the five highest mortality EGS procedures. Second, as previous studies have determined that the proportion of geriatric patients treated at a hospital is more predictive of outcomes versus the number of geriatric patients,[21,22] we additionally evaluated hospital proportion of geriatric patients with outcomes. Third, because rates of in-hospital mortality may be subject to survivor bias, we performed a log-rank test after censoring patients with lengths of hospital stay greater than 30 days. Finally, additional univariable and multivariable logistic regressions assessed the associations between both surgeon and hospital geriatric-EGS volume categories with each of the eight individual complications. All multivariable regressions and the log-rank test accounted for confounding by adjusting for patient age, gender, race, and ethnicity, Elixhauser score, payer, hospital beds, region, teaching affiliation, and EGS procedure, as well as incorporated robust standard errors to account for correlations of outcomes within individual hospitals. Analyses were performed in STATA 14.2 (StataCorp, College Station, TX). This study was exempted from the Johns Hopkins Institutional Review Board.

RESULTS

We identified 3,832 patients who met criteria for analysis in Maryland from July 1, 2012 to September 30, 2014. Most patients were white (71.4%) and had Medicare (87.9%), and over half were women (53.6%) and were 65–74 years of age (52.3%). Surgeons who graduated from medical school within 15 years operated on 14.8% of all patients. Several characteristics varied between low-volume surgeons and high-volume surgeons (Table 1).

The most common procedures were cholecystectomies (27.7%), open large bowel excisions (14.2%), and peritoneal adhesiolysis (14.2%). The least common procedures were anterior abdominal wall hernia repair (3.2%), a laparotomy (2.6%), and a perirectal tissue incision or excision (1.0%) (Table 2).

TABLE 1. Demographics of Patients 65 Years or Older Undergoing EGS Procedures

	All Procedures	Low-volume Surgeons (≤8 EGS Cases/Year)	High-volume Surgeons (>8 EGS Cases/Year)	*p*
Number (N)	3832	633 (16.5%)	3199 (83.5%)	
Gender				0.13
Male	46.5%	49.1%	45.2%	
Female	53.6%	50.9%	54.1%	
Race and ethnicity				<0.01
White	71.4%	64.3%	72.8%	
Black	17.0%	22.8%	15.8%	
Hispanic ethnicity	2.0%	2.1%	1.9%	
Other/missing	9.7%	10.9%	9.4%	
Age				0.08
65–74	52.3%	56.4%	51.5%	
75–84	32.4%	29.5%	33.0%	
85+	15.3%	14.1%	15.5%	
Comorbidities				0.76
0–1	17.1%	18.0%	16.9%	
2–4	50.0%	49.0%	50.2%	
5+	32.9%	33.0%	32.9%	
Payer				0.33
Private	9.9%	11.4%	9.6%	
Medicare	87.9%	85.9%	88.3%	
Medicaid	1.0%	1.1%	1.0%	
Self-pay	1.1%	1.6%	1.0%	
Hospital beds				<0.01
≤200 beds	21.7%	17.2%	22.5%	
201–400 beds	58.4%	36.8%	62.6%	
>400 beds	20.0%	46.0%	14.9%	
Region				<0.01
Urban	92.5%	89.6%	93.0%	
Rural	7.5%	10.4%	7.0%	
Teaching affiliation				<0.01
Teaching	50.0%	70.5%	45.9%	
Non-teaching	50.0%	29.5%	54.1%	
Surgeon years since medical school				<0.01
≤15 years	14.8%	25.6%	12.7%	
>15 years	83.6%	74.4%	85.4%	
Unknown	1.6%	0.0%	1.9%	

There was an overall mortality rate of 4.7% (ranging from 0.0% for a perirectal tissue incision or excision to 24.0% for a laparotomy), a complication rate of 27.0% (ranging from 11.2% for an appendectomy to 59.0% for a laparotomy), failure-to-rescue rate of 15.0% (range from 0.0% for a perirectal tissue incision of excision to 35.6% for a laparotomy), and a 30-day readmission rate of 11.5% (ranging from 7.9% for an appendectomy to 16.7% for an umbilical hernia repair). Of the 181 patients who died, 37.6% died within 2 days of their procedure and another 21.6% died within the following 5 days.

There were 302 surgeons operating at 44 hospitals. Large variations existed in annual geriatric-EGS volumes among both surgeons (median: 8 geriatric-EGS/year, IQR 3–18) and hospitals (median: 82 geriatric-EGS/year, IQR 35–132). Using the median volume as the threshold, we identified 161 (53.3%) low-volume surgeons (≤8 geriatric-EGS/year) and 141 (46.7%) high-volume surgeons (>8/year), along with 22 (50.0%) low-volume hospitals (≤82 geriatric-EGS/year) and 22 (50.0%) high-volume hospitals (>82/year). Low geriatric-EGS volume surgeons operated on 16.5% of all geriatric EGS patients. Nearly one-third of all high-volume surgeons (45/141, 31.9%) operated at low-volume hospitals, while two-thirds of all low-volume surgeons (115/161, 71.4%) operated at high-volume centers. Patients operated on by low geriatric-EGS volume surgeons had higher risk-adjusted outcomes compared to those operated on by high geriatric-EGS volume surgeons (mortality: 7.0% vs. 4.0%, $p = 0.005$; in-hospital complications: 22.1% vs. 19.7%, $p = 0.13$; failure-to-rescue: 17.3% vs. 12.1%, $p = 0.021$; and 30-day readmissions: 11.2% vs. 10.0%, $p = 0.55$) (Fig. 1).

Multivariable logistic regressions calculated associations between surgeon and hospital volume categories with the four outcomes and met goodness-of-fit criteria by the Hosmer–Lemeshow and AUC tests (Table 3). After adjusting for all patients and hospital factors and hospital clustering, patients operated on by low geriatric-EGS volume surgeons relative to those operated on by high geriatric-EGS volume surgeons experienced greater mortality (adjusted odds ratio [aOR] 1.86, 95% confidence interval [1.21–2.86]), similar in-hospital complications (aOR 1.20 [0.95–1.51]), but greater failure-to-rescue rates (aOR 1.74 [1.09–2.80]). No difference existed with 30-day readmissions (aOR 1.07 [0.85–1.34]). In contrast, patients operated on by low geriatric-EGS volume hospitals relative to those operated on by high geriatric-EGS volume hospitals were not associated with higher rates for any distinct outcome: mortality (aOR 0.91 [0.56–1.48]), in-hospital complications (aOR 0.97 [0.76–1.25]), failure-to-rescue (aOR 0.83 [0.48–1.41]), or 30-day readmissions (aOR 0.92 [0.72–1.18]). Sensitivity analyses that repeated the four previous regressions using surgeon and hospital volume categories created from median annual volumes of all adult EGS procedures (patients 20 years of age or older) found no associations between outcomes and low-volume surgeons (mortality: aOR 1.05 [0.62–1.75], in-hospital complications: aOR 1.15 [0.93–1.42], failure-to-rescue: aOR 0.94 [0.55–1.60], 30-day readmissions: aOR 1.15 [0.90–1.47]) or low-volume hospitals (mortality: aOR 0.89 [0.54–1.46], in-hospital complications: aOR 1.04 [0.79–1.37], failure-to-rescue: aOR 0.87 [0.50–1.52], 30-day readmissions: aOR 1.04 [0.82–1.30]).

Subgroup analysis on the five highest mortality procedures (open large intestine excision, small intestine excision, peritoneal adhesiolysis, control of stomach or duodenum ulcer and hemorrhage, and exploratory laparotomy) yielded the same significant and non-significant findings as above between surgeon and hospital volume categories with outcomes. Next, we categorized hospitals by their proportion of geriatric EGS patients in both tertiles and in quartiles. After adjustment, no differences existed in any of the four outcomes between the top and bottom tertiles or quartiles of hospitals (Table 4). To evaluate the impact of survivor bias when analyzing in-hospital mortality rates, we also performed a log-rank test which censored patients with lengths of hospital stay greater than 30 days. After adjustment, we found that our findings remained the same, where low geriatric-EGS volume surgeons (hazards ratio 2.22 [95%

TABLE 2. Overall and Procedure-Specific Mortality, Complications, and 30-Day Readmission Rates

	Number	Mortality	Complications	Failure-to-rescue*	30-Day Readmission
All EGS procedures	3832	181 (4.7%)	1035 (27.0%)	155 (15.0%)	440 (11.5%)
Cholecystectomy	1062 (27.7%)	4 (0.4%)	149 (14.0%)	4 (2.7%)	92 (8.7%)
Open large intestine excision	545 (14.2%)	71 (13.0%)	260 (47.7%)	62 (23.9%)	89 (16.3%)
Peritoneal adhesiolysis	544 (14.2%)	19 (3.5%)	146 (26.8%)	16 (11.0%)	63 (11.6%)
Appendectomy	493 (12.9%)	4 (0.8%)	55 (11.2%)	2 (3.6%)	39 (7.9%)
Small intestine excision	272 (7.1%)	34 (12.5%)	121 (44.5%)	26 (21.5%)	40 (14.7%)
Unilateral inguinal hernia repair	206 (5.4%)	4 (1.9%)	38 (18.5%)	4 (10.5%)	23 (11.1%)
Excision of lesion, tissue, or subcutaneous tissue	187 (4.9%)	3 (1.6%)	67 (35.8%)	3 (4.5%)	27 (14.4%)
Umbilical hernia repair	132 (3.4%)	1 (0.8%)	26 (19.7%)	1 (3.9%)	22 (16.7%)
Control of stomach or duodenum ulcer and hemorrhage	128 (3.3%)	14 (10.9%)	85 (66.4%)	14 (16.5%)	15 (11.7%)
Anterior abdominal wall hernia repair	123 (3.2%)	3 (2.4%)	21 (17.1%)	2 (9.5%)	15 (12.2%)
Laparotomy	100 (2.6%)	24 (24.0%)	59 (59.0%)	21 (35.6%)	13 (13.0%)
Perirectal tissue incision or excision	40 (1.0%)	0 (0.0%)	8 (20.0%)	0 (0.0%)	2 (5.0%)

*Failure-to-rescue defined as the proportion of patients who died after experiencing a postoperative complication. Hence, the denominator for the percentages are patients who experienced a postoperative complication.

CI 1.46–3.38]) but not low geriatric-EGS volume hospitals (0.76 [0.44–1.31]) were associated with increased mortality relative to their high-volume counterparts.

Additional univariable and multivariable logistic regressions assessed the associations between geriatric-EGS surgeon volume categories and specific in-hospital complications (Table 5). On univariable analysis, patients operated on by low geriatric-EGS volume surgeons were associated with higher rates of SSIs (p = 0.04), hemorrhage (p = 0.002), and DVT/PEs (p = 0.03) relative to patients operated on by high geriatric-EGS volume surgeons. After adjustment, only a higher rate of hemorrhage remained significant among low geriatric-EGS volume surgeons (p = 0.02). Adjusting for surgeon clustering instead of hospital clustering resulted in similar significant and non-significant findings in all analyses.

DISCUSSION

Emergency general surgical operations among geriatric patients have become a growing public health challenge.[17,23] This contemporary statewide data analysis demonstrated that surgeon geriatric-EGS volume, but not hospital geriatric-EGS volume or hospital proportion of geriatric-EGS patients, is associated with adverse outcomes. Specifically, while low geriatric-EGS volume surgeons operated on one-sixth of all geriatric-EGS patients in Maryland, they were associated with higher mortality rates, greater rates of failure-to-rescue, and had associations with specific in-hospital complications. We found no evidence that hospitals experiencing low geriatric-EGS volumes or low proportions of such patients were associated with adverse mortality, in-hospital complications, failure-to-rescue or 30-day readmission rates relative to high geriatric-EGS volume or proportion hospitals. These findings raise noteworthy concerns for the field of geriatric surgery, especially given the relatively high rate of adverse outcomes among EGS-geriatric patients as well as the rapidly aging US population.

There are several reasons why geriatric patients in this study undergoing EGS procedures may experience high rates of adverse outcomes. Geriatric patients are physiologically more complex in terms of, for example, nutritional status, sarcopenia, and pulmonary compliance, and are socioeconomically different from younger patients regarding support systems and functional

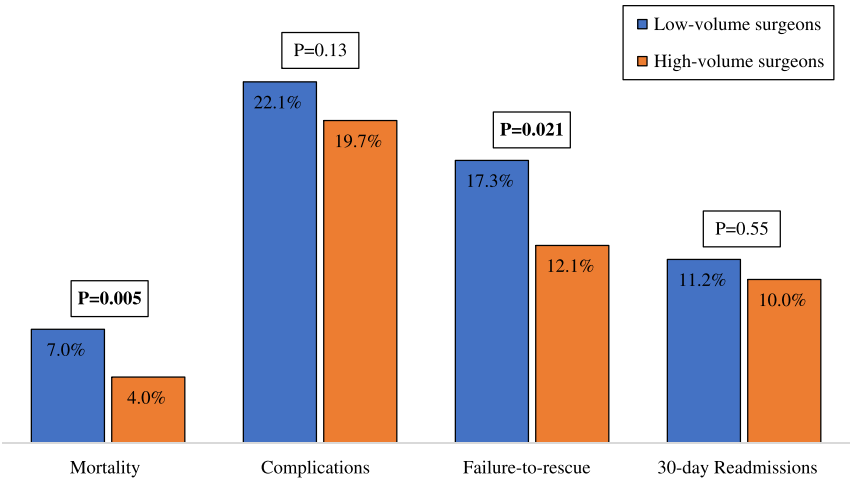

Figure 1. Risk-adjusted outcomes by surgeon geriatric-EGS volume categories.

TABLE 3. Adjusted Associations Between Patient, Surgeon, and Hospital Characteristics With EGS Outcomes Among Geriatric Patients

	Mortality			
	*Adjusted Odds Ratio (95% Confidence Interval)	Complications	Failure-to-rescue	30-Day Readmissions
Surgeon volume				
Low-volume	1.86 (1.21–2.86)	1.20 (0.95–1.51)	1.74 (1.09–2.80)	1.07 (0.85–1.34)
High-volume	Reference	Reference	Reference	Reference
Hospital volume				
Low-volume	0.91 (0.56–1.48)	0.97 (0.76–1.25)	0.83 (0.48–1.41)	0.92 (0.72–1.18)
High-volume	Reference	Reference	Reference	Reference
Surgeon years since medical school				
≤15 years	1.17 (0.71–1.91)	1.05 (0.83–1.33)	0.98 (0.61–1.58)	0.93 (0.74–1.17)
>15 years	Reference	Reference	Reference	Reference
Gender				
Female	0.91 (0.70–1.17)	0.74 (0.62–0.88)	0.99 (0.76–1.29)	1.26 (1.02–1.54)
Male	Reference	Reference	Reference	Reference
Age				
65–74	Reference	Reference	Reference	Reference
75–84	1.75 (1.25–2.44)	1.34 (1.12–1.60)	1.33 (0.92–1.92)	1.21 (0.93–1.56)
85+	2.36 (1.39–4.00)	1.35 (1.04–1.75)	2.17 (1.31–3.59)	1.23 (0.85–1.78)
Race and ethnicity				
White	Reference	Reference	Reference	Reference
Black	1.24 (0.78–1.96)	1.43 (1.19–1.71)	0.99 (0.54–1.80)	1.20 (0.90–1.59)
Hispanic ethnicity	0.48 (0.06–4.14)	1.37 (0.91–2.04)	—	1.55 (0.73–3.27)
Other/missing	0.78 (0.47–1.28)	0.81 (0.58–1.14)	0.89 (0.54–1.49)	0.86 (0.62–1.21)
Comorbidities				
0–1	Reference	Reference	Reference	Reference
2–4	2.29 (0.75–6.96)	3.53 (2.25–5.52)	0.52 (0.14–1.94)	1.47 (1.10–1.98)
5+	7.65 (2.63–22.27)	11.37 (7.03–18.40)	0.61 (0.40–0.94)	2.53 (1.78–3.61)
Payer				
Private	1.51 (0.86–2.64)	1.09 (0.75–1.58)	—	0.98 (0.75–1.29)
Medicare	Reference	Reference	Reference	Reference
Medicaid	1.57 (0.39–6.27)	1.37 (0.69–2.71)	0.55 (0.12–2.58)	1.23 (0.55–2.76)
Self-pay	0.54 (0.07–4.05)	1.20 (0.55–2.60)	0.70 (0.11–4.37)	1.70 (0.77–3.76)
Teaching affiliation				
Teaching	Reference	Reference	Reference	Reference
Non-teaching	0.72 (0.43–1.22)	0.92 (0.73–1.15)	0.78 (0.41–1.48)	0.78 (0.62–0.99)
Hospital beds				
≤200 beds	1.40 (0.92–2.14)	1.01 (0.66–1.54)	1.89 (1.10–3.23)	1.48 (1.10–2.00)
201–400 beds	Reference	Reference	Reference	Reference
>400 beds	0.79 (0.35–1.75)	0.88 (0.63–1.24)	1.03 (0.42–2.53)	1.25 (0.99–1.57)
Region				
Urban	Reference	Reference	Reference	Reference
Rural	0.91 (0.39–2.11)	0.90 (0.51–1.60)	0.91 (0.38–2.21)	0.72 (0.40–1.30)

*These models adjusted for surgeon and hospital geriatric-EGS volume categories, patient gender, age, race, number of comorbidities, payer, teaching affiliation, beds, region, and hospital clusters.

independence.[24] As the chronologic age of patients increase, their physiologic reserve also decreases, and while many geriatric patients can handle postoperative stress, they may subsequently handle severe stress poorly. A patient's physiologic reserve further decreases under emergent procedures because there are fewer opportunities to preoperatively optimize the patient's medical conditions.[25,26] Moreover, acquiring preoperative cardiac, renal, and pulmonary tests in these patients is often not possible in the emergent setting and still may not provide adequate risk mitigation when available.[27] The significant adverse EGS outcomes documented in this study underscore the need for focused care of elderly surgical patients. Of note, the mortality rate in this study is still lower than that reported in other studies and may be because of the inclusion of lower mortality procedures (i.e., appendectomy, cholecystectomy) or due to not identifying cases of death after discharge but within 30 days of the procedure.

With regard to surgeon volume and geriatric-EGS outcomes, there were two important findings. First, low geriatric-EGS volume surgeons were associated with 86% higher odds of mortality and 74% higher odds of failure-to-rescue in elderly patients. This is in keeping with similar documented associations between volume and outcomes in other surgical fields

TABLE 4. No Observed Difference in EGS Outcomes by the Proportion of Geriatric Patients Served at Hospitals

	Hospitals	Patients	Mortality	Any Complication	Failure-to-rescue	Readmission
	N (%)	N (%)	Adjusted Odds Ratio* (95% Confidence Interval)			
Tertiles						
1st (<22.7% geriatric patients)	15 (34.1%)	817 (21.3%)	1.39 (0.79–2.42)	1.12 (0.81–1.53)	1.51 (0.74–3.06)	1.23 (0.88–1.71)
2nd (22.7% to 28.0%)	14 (31.8%)	1501 (39.2%)	1.05 (0.61–1.82)	1.05 (0.82–1.35)	0.95 (0.46–1.99)	1.15 (0.91–1.46)
3rd (>28.0%)	15 (34.1%)	1514 (39.5%)	Reference	Reference	Reference	Reference
Quartiles						
1st (<21.4% geriatric patients)	11 (25.0%)	552 (14.4%)	1.43 (0.77–2.65)	1.14 (0.75–1.75)	1.81 (0.87–3.76)	1.31 (0.88–1.96)
2nd (21.4% to 25.3%)	11 (25.0%)	1336 (34.9%)	1.08 (0.59–1.96)	1.12 (0.80–1.58)	1.03 (0.45–2.38)	1.20 (0.88–1.65)
3rd (25.4% to 31.5%)	11 (25.0%)	956 (25.0%)	0.80 (0.48–1.32)	1.06 (0.77–1.47)	0.94 (0.48–1.81)	0.97 (0.71–1.32)
4th (>31.5%)	11 (25.0%)	988 (25.8%)	Reference	Reference	Reference	Reference

*These models adjusted for either hospital tertiles or quartiles, patient gender, age, race, number of comorbidities, payer, teaching affiliation, beds, region, and hospital clusters.

(elective general, trauma, orthopedic, and gynecologic).[28–34] Indeed, higher volume surgeons may be associated with greater proficiency, as was shown in Birkmeyer et al.'s landmark study where surgeon skill was associated with postoperative complication rates.[35] Lower volume surgeons may also be less experienced with decision-making with regards to operating on patients who may inevitably die from their medical and surgical conditions. Second, when recreating surgeon volume categories using all EGS procedures performed among adult patients (20 years of age or older) in our sensitivity analyses, there was no longer a significant association between patients operated on by low-volume surgeons and mortality. As case volume defined specifically in terms of geriatric EGS patients, as opposed to all adult EGS patients, was associated with distinct outcomes, it further highlights the unique challenges involved in operating on and managing an elderly patient. These findings highlight that further initiatives are needed to aid all surgeons in caring for the geriatric patient. Accordingly, some have argued for the development of Geriatric Surgery Institutes,[36] which would "house multidisciplinary teams of physicians who provide focused consultations" and "ancillary services specialized in the care of at-risk elderly patients, aggressive rehabilitation, and palliative care consultation." Previous studies evaluating the creation of either specific EGS services or geriatric patient services have also begun showing promising results.[37–39] Likewise, establishing a collaboration between both services may benefit elderly patients.

Our results showing that low geriatric-EGS volume surgeons were not associated with higher overall complication rates, but were associated specifically with hemorrhage on multivariable analysis and both SSIs and DVT/PEs on univariable analyses, deserves attention. Numerous studies have documented how team culture affects the management of complications,[40–42] which could remove any association between surgeon volume and complications. These findings may also be a reflection of process improvement measures rather than volume. For example, the Implementation of Best Practice Guidelines[43,44] and Enhanced Recovery After Surgery (ERAS) protocols[45] have decreased complications, length of stays, and 30-day readmission rates in several series. As our study could not evaluate which hospitals adopted, and to what extent implemented, best practice guidelines, these process measures likely confounded results. Additionally, while we measured a robust set of complications common to EGS procedures, we may not have evaluated those specific enough for the geriatric population, such as delirium and pressure ulcers, as well as additional patient-centered outcomes particular to the elderly, such as dependence. Finally, the significantly greater rate of failure-to-rescue among lower volume surgeons in this study also highlights the importance of the management after the first postoperative complication and subsequently warrants further investigation.

We did not find any associations between hospital geriatric-EGS volume or proportion of geriatric-EGS patients with outcomes. While many previous statewide or nationwide studies

TABLE 5. Adjusted Associations Between Surgeon Volume Categories and Individual Complications

Complication	All patients	Low-volume Surgeons	High-volume Surgeons	*p*	
				Unadjusted	Adjusted*
Acute renal failure	679 (17.7%)	112 (17.7%)	567 (17.7%)	0.99	0.79
Pulmonary failure	270 (7.1%)	50 (7.9%)	220 (6.9%)	0.58	0.86
Surgical site infection	153 (4.0%)	38 (6.0%)	115 (3.6%)	0.04	0.36
Gastrointestinal bleed	113 (3.0%)	23 (3.6%)	90 (2.8%)	0.34	0.53
Pneumonia	108 (2.8%)	17 (2.7%)	91 (2.8%)	0.81	0.91
Hemorrhage	89 (2.3%)	26 (4.1%)	63 (2.0%)	0.002	0.02
Myocardial infarction	62 (1.6%)	10 (1.6%)	52 (1.6%)	0.93	0.81
DVT/PE	23 (0.6%)	8 (1.3%)	15 (0.5%)	0.03	0.10
ALL complications	1035 (27.0%)	196 (31.0%)	839 (26.2%)	0.17	0.13

*These models adjusted for surgeon and hospital geriatric-EGS volume categories, patient gender, age, race, number of comorbidities, payer, teaching affiliation, beds, region, and accounted for hospital clusters.

have found a hospital effect with outcomes,[46,47] most, if not all, of them did not assess the impact of surgeon volume. However, we do not conclude that hospital volume or proportion of geriatric patients is not associated with outcomes for several reasons. There may be some selection bias, in particular related to transfer of more complex patients from smaller, low-volume hospitals to larger, academic, high-volume hospitals. Our dataset also did not provide us with more granular hospital-level data to include in our analyses, such as nursing staff, technicians, and imaging availabilities. Even with the development of best practices, perioperative practices likely differ across hospitals. Furthermore, the marked variation in surgeon volumes within hospitals may have influenced hospital effects, given that one-third of high-volume surgeons operated at low-volume hospitals, and two-thirds of low-volume surgeons operated at high-volume hospitals. Using the National Trauma Data Bank, Zafar et al. found that trauma centers serving a greater proportion of geriatric patients had lower odds of death among the elderly patient experiencing trauma,[22] and this may hold true for and requires future investigation among EGS patients. Our results suggest that the development of volume guidelines pertaining to geriatric-EGS patients should account for surgeon volume, in addition to hospital volume.

Over the past decade, there have been substantial improvements in the care of geriatric patients and the development of training programs specific to their treatment. The American College of Surgeons developed Best Practice Guidelines for optimizing both preoperative[43] and perioperative care[44] for the geriatric patient and have recently started their Geriatric Surgery Verification and Quality Improvement Program to "define the processes, resources, and infrastructures necessary for the optimal care of the older adult surgical patient." The creation of geriatric surgery fellowships directly encourages the development of high geriatric-volume surgeons, which benefits elderly patients undergoing EGS procedures. Finally, the Geriatric Trauma Coalition, composed of specialists in Acute Care and Trauma Surgery, Trauma Nursing, and Geriatrics and Gerontology, serves as an interdisciplinary model to improving outcomes in geriatric patients by involving multiple stakeholders.[48]

Our study has several important limitations and proposes future considerations. First, as with all studies using administrative data, there may be missing variables, miscoding of procedures, and a lack of important characteristics that can impact an EGS procedure in a geriatric patient. For example, while there has been a great amount of work on "frailty" in the elderly and how frailty indices can identify high-risk patients,[23,49,50] our database did not allow us to include characteristics of frailty, besides age and comorbidities. Second, while we accounted for several important hospital characteristics (i.e., beds, academic status, and region), there may be other hospital characteristics that differ across the state and affect a surgeon's outcomes after an EGS procedure, such as having a dedicated acute care surgery service. Third, we could not create volume categories using quartiles, as there were too few counts of outcomes within the lowest volume categories for statistical analysis. Fourth, we did not account for the specific diagnosis necessitating the emergent procedure. Fifth, to continue studying EGS outcomes and address potential survivor bias (i.e., post-discharge mortality), prospective studies or datasets should track patients after discharge for survival analyses. Finally, while using a statewide database prevents us from applying necessary weights for estimating nationwide statistics, this database provides important surgeon-level information that is often absent in nationwide databases.

CONCLUSION

The geriatric population in the state of Maryland faces significantly high rates of mortality, complications, failure-to-rescue, and 30-day readmissions after emergency general surgeries. Additionally, geriatric patients operated on by surgeons performing eight or fewer geriatric-EGS procedures annually were associated with an 86% higher odds of death and 74% higher odds of failure-to-rescue, and were also associated with specific in-hospital complications. As these low-volume surgeons operated on one out of every six geriatric EGS patients, our concerning findings warrant the development of specific services and quality programs geared toward the care of the geriatric patient undergoing an EGS procedure.

AUTHORSHIP

All authors contributed to at least one of the following: study design (A.M., L.A.D., B.J., D.T.E., J.V.S.), data acquisition (A.M., J.K.C.), analysis or interpretation of data (A.M., L.A.D., B.J., J.K.C., K.S., C.J., E.R.H., D.T.E., J.V.S.), manuscript draft (A.M.), critical revision and final approval of the manuscript (A.M., L.A.D., B.J., J.K.C., K.S., C.J., E.R.H., D.T.E., J.V.S.).

DISCLOSURE

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DISCUSSION

Dr. Zara Cooper (Boston, Massachusetts): Good afternoon. I'd like to thank Drs. Coimbra, Spain, Crandall and Holcomb for the privilege of the podium.

I'm honored to discuss this paper by Dr. Sakran and his colleagues, Emergency General Surgery in Geriatric Patients: A Statewide Analysis of Surgeon and Hospital Volumes with Outcomes.

And I congratulate Dr. Sakran on an excellent presentation and he and his authors on a very well-written and provocative paper that examines the association between hospital volume and surgeon volume with respect to adverse outcomes for older EGS patients.

In this analysis the authors used the Maryland State Database from 2012 to 2014 to identify older patients who had one of 12 common and highly morbid EGS procedures.

Here they stratified surgeons by volume, less than eight geriatric EGS procedures a year as the cut-off for low volume, and stratified hospitals by volume, using fewer than 82 geriatric EGS procedures per year as the cutoff for low volume.

The outcomes of interest included in-hospital mortality, complications, and 30-day readmission. And here they found that low-volume surgeons were associated with an 86 percent increased risk of mortality in older patients.

After sensitivity analysis in all adult patients there was no difference in mortality between high- and low-volume surgeons. Hospital volume had no association with mortality, complications or re-admission.

And these findings suggest that patients who receive care from surgeons who perform more EGS, geriatric EGS procedures have lower odds of in-hospital mortality and also support ongoing efforts to improve the quality of surgery for older patients. For that I commend the authors.

This study adds to the current literature by identifying a modifiable factor – namely, the operating surgeon – that can be targeted to improve outcomes in some of our most vulnerable patients. And, as the authors clearly outline, this is sorely needed in EGS.

EGS procedures, in general, are associated with very high morbidity and complication rates. And our understanding of this difference has largely centered upon the unexpected nature of EGS as well as the acuity of illness of our patients, their comorbidities, their frailty, underlying illness risk.

Previous literature has looked at systems of care as contributors to poor outcomes. However, the field of acute care surgery was born, in part, as a way to systematize care to reduce variation and improve outcomes.

But the uneasy conclusion of this paper is that the most significant contributor to variation in outcome is us, the operating surgeon, and that receiving care under a low-volume surgeon, whom, by the way, patients rarely choose, may be a death sentence.

The implications here are that, 1, EGS procedures should be limited to high-volume surgeons and 2, that unlike other areas of surgery, including trauma, hospital volume is not associated with outcomes.

So I have a number of comments and questions.

One. Mortality in this study was 4.7 percent, which is lower than similar studies of mortality in older EGS patients. And I wonder, why do you think that is? And how could low mortality in this study have influenced your findings?

Two. The authors recently published another paper using the same dataset to examine the volume/outcome relationship for all adult patients, as Dr. Sakran mentioned.

Here they controlled for complexity of the procedure. How did you account for procedure complexity in this analysis? And if you did not, how might this have biased your results?

Three. Seminal studies by Dimik and Birkmeyer, also mentioned in this presentation, examined the volume/outcome relationship in surgery, have stratified by hospital and surgeon volume in quintiles to achieve a more nuanced understanding of the volume/outcome relationship.

Other studies in trauma and acute care surgery have looked at tertiles and quartiles to stratify hospitals. However, you chose to stratify surgeon volume by the median. Why use the median which is very coarse approach to distinguish the highest and lowest performers?

Aforementioned papers in other surgical populations have shown that hospital volume is associated with better outcomes in complex surgical procedures.

Your findings suggest that EGS is different. Why isn't lower hospital volume associated with worse outcomes in EGS as it is in other surgical populations?

Of note, work from our group has shown that trauma centers that care for a higher proportion of geriatric patients, irrespective of their volume, have lower mortality. Please consider taking steps to account for geriatric EGS proportion in your analysis.

And, finally, low-volume geriatric EGS surgeons had similar rates of complications and readmissions than higher-volume surgeons, suggesting that patients who survived surgery fared equally well or poorly, as it may be. Why do you think there is a difference in mortality as opposed to the other outcomes?

Sensitivity analysis, which used data from all adult patients, found no associations between surgeon volume and outcomes, suggesting that the experience threshold is higher for geriatric patients.

Experience and observation will tell you that making the decision to proceed with surgery or to forego surgery is perhaps the most difficult part of caring for these patients.

Surgeons have also told us in prior studies that prognostic uncertainty and the time pressures associated with these scenarios impede preoperative discussions about goals of care and often make it easier to just take the patient to the operating room when the expected outcome is, in fact, death.

Is it possible that a major contributor to higher mortality is poor patient selection among inexperienced surgeons? I understand that administrative data lacks the granular clinical variables to address this question.

I think that this study represents the beginning of a novel line of inquiry and I implore the authors to dig deeper. Forty-four hospitals is not that many. And so I would really hope that you will continue with your work in primary data collection.

I thank you for the privilege of the podium.

Dr. David A. Spain (Stanford, California): My question gets to Dr. Cooper's last point. I'm not sure it's just volume. I think the issue might be the low-volume, low-experienced surgeon.

Now I'm not as old as Dr. Jurkovich, but as I approach the age of a geriatric patient, I'm not sure that at 57 years old that I need the same volume of experience each year to keep my skills up as I did at 37. So do you have any way to look at not just volume but collective experience of surgeons? Sorry, Jerry.

Dr. Gregory J. "Jerry" Jurkovich (Sacramento, California): Really nice paper and a terrific discussion, Zara. I liked it a lot.

It's so tempting to use volume as a surrogate for performance and to say that if you are failing it is because you're not seeing enough of these patients. One has to resist coming to that easy conclusion and look for as many other explanations as you possibly can. So let me put three explanations forward and ask you if you investigated them in this study.

One. Since hemorrhage was a major complication, were there more anticoagulant used in the hemorrhage population than in those that didn't die? Is that possibly one of the reasons?

Number 2. The proportion of elderly patients seen in the hospital, as Dr. Cooper mentioned, is an important variable here because it's not just the surgeon; it's across the whole system and how used to dealing with elderly are all providers.

For example, some evidence suggests that urban Level I trauma centers don't do the best job of taking care of the elderly patients; Community Level IIs do a better job of taking care of the elderly patients.

If true, this might be because the community Level II are used to seeing more of those patients and develop a system to provide that care. Is that what is going on here is just the proportion of elderly in these low-volume hospitals?

And the third point is when did the patients die? Did they die in the ICU? Did they die days later? Did they die in the operating room? Can you give us any information on the timing of death? Well done. Thank you.

Dr. Robert A. Maxwell (Chattanooga, Tennessee): Bob Maxwell, Chattanooga. Interesting paper. I was wondering if the codes you used to pull these cases, if you were able to identify which patients may have undergone a laparoscopic procedure and if there was a higher incidence of laparoscopic procedures being done at the higher-volume centers and maybe this would have had an impact on the frailty factor and the recovery of some of these older people. Thank you.

Dr. David J. Ciesla (Tampa, Florida): Dave Ciesla from Tampa. I just, a little bit of follow-up on something Dr. Cooper said and what Dr. Spain and Jurkovich said.

If you want to limit the care of these patients to the experienced surgeons, first of all, how do you get to be an experienced surgeon?

Second of all, the experienced surgeons usually are approaching 57 or something like that. And since most emergency general surgery is done by taking call, how do you keep 57-year old experienced surgeons interested in taking call?

Dr. Joseph V. Sakran (Baltimore, Maryland): All right, well, thank you for those great questions and thanks, specifically, to Dr. Cooper who has done so much work in this field and really provided us with a thoughtful way to discuss this topic.

First, in regards to mortality, one of the things that I should point out is that this finding may have had to do with our case mix.

You know there was a variation in mortality anywhere from zero in those that got a perirectal drainage to 24% in patients who had laparotomies. This could very well be one reason.

The other difference could be differences in the characteristics of our sample. Perhaps other studies had older patients or it could be that maybe frailty was a factor. It's really hard to assess for those variables.

Finally, looking forward I think one of the things that we could potentially do is categorize groups into low- and high-risk procedures and maybe that will provide us with a better way to look at this and see if these outcomes still remain the same.

In regards to median, there is a number of different ways to look at surgeon volume and no real objective method, currently. And as Dr. Cooper pointed out, there is a number of potential ways to look at this. Some people have done quartiles. Some have done tertiles. There has been some that have looked at medians, which is very coarse.

However, one of the things in our study that we wanted to ensure, considering we were working with a limited sample of just geriatric patients is that we had enough individuals in both groups in order to make a fair comparison because we didn't want to analyze something that had really too few complications that would, then, not really mean anything to any of us.

Finally, I think in regards to hospital volume and complications, this is a really important point. And one of the things that we couldn't do in our study is really figure out institutional variation.

So perhaps there is some effect from a performance improvement standpoint, and it could even have to do with practice management guidelines implemented at institutions.

All these variations are very difficult to account for. And this, also, lends to the fact that you know part of the institutional variation deals with teamwork and culture, which we know from prior data is actually extremely important when you are looking at complications.

The final thing in regards to complications is whether are we seeing these findings as an effect of failure to rescue?

We saw this yesterday in a paper that we presented where the complication rate had been mildly elevated or slightly positive but the mortality was significantly different.

And it had to do with the system's ability to really be able to rescue a patient once they actually had the complication.

When we are talking about surgeon experience, let me just illustrate what we did since a few people have asked about this. Because a couple of people pointed this out and this is a very important point, and I don't know that I have the right answer but let me tell you what we did.

In our database we were able to look at surgeon experience from the time physicians graduated medical school. We divided up the surgeons into two groups. We looked at those who have graduated from medical school over 15 years ago and those within 15 years of graduation.

The reason we chose 15 years is because we wanted to give adequate time account for training (residency, fellowship, research), and then enough time as a junior attending where it takes time to build up some experience and sharpens ones clinical skills. We found no a difference between those two groups.

Is this classification necessarily the right thing to use? I'm not sure. Maybe it's five years or maybe there is a different

number we are yet not aware of. This is an area of research that we look forward to investigating in the future.

I think that the anticoagulation question is a really good one. We always talk about it in trauma. And we didn't have that variable available to us in our database. Nor did we have, the other variable in question, timing of death.

Those are both really important topics, and we hope to find better methods to look at those factors as we move forward in the future.

The question asked about laparoscopy is interesting, and that analysis was not included in our study.

Finally, to answer the philosophical question about how we keep people taking call. That I am not sure about, but hopefully we can figure it out as a collective group of individuals that one day may be in need of services provided by acute care surgeons.

Thank you all so much for your attention. It was a pleasure to be up on the podium.