Hospitals with higher volumes of emergency general surgery patients achieve lower mortality rates: A case for establishing designated centers for emergency general surgery

Gerald O. Ogola, PhD, MPH, Adil Haider, MD, *and* **Shahid Shafi, MD, MPH**, *Dallas, Texas*

AAST Continuing Medical Education Article

Accreditation Statement

This activity has been planned and implemented in accordance with the Essential Areas and Policies of the Accreditation Council for Continuing Medical Education through the joint providership of the American College of Surgeons and the American Association for the Surgery of Trauma. The American College Surgeons is accredited by the ACCME to provide continuing medical education for physicians.

AMA PRA Category 1 CreditsM™

The American College of Surgeons designates this journal-based CME activity for a maximum of 1 *AMA PRA Category 1 Credit*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Of the *AMA PRA Category 1 Credit*™ listed above, a maximum of 1 credit meets the requirements for self-assessment.

Credits can only be claimed online

AMERICAN COLLEGE OF SURGEONS

Inspiring Quality:
Highest Standards, Better Outcomes

100+*years*

Objectives

After reading the featured articles published in the *Journal of Trauma and Acute Care Surgery*, participants should be able to demonstrate increased understanding of the material specific to the article. Objectives for each article are featured at the beginning of each article and online. Test questions are at the end of the article, with a critique and specific location in the article referencing the question topic.

Claiming Credit

To claim credit, please visit the AAST website at http://www.aast.org/ and click on the "e-Learning/MOC" tab. You must read the article, successfully complete the post-test and evaluation. Your CME certificate will be available immediately upon receiving a passing score of 75% or higher on the post-test. Post-tests receiving a score of below 75% will require a retake of the test to receive credit.

Disclosure Information

In accordance with the ACCME Accreditation Criteria, the American College of Surgeons, as the accredited provider of this journal activity, must ensure that anyone in a position to control the content of *J Trauma Acute Care Surg* articles selected for CME credit has disclosed all relevant financial relationships with any commercial interest. Disclosure forms are completed by the editorial staff, associate editors, reviewers, and all authors. The ACCME defines a `commercial interest' as "any entity producing, marketing, re-selling, or distributing health care goods or services consumed by, or used on, patients." "Relevant" financial relationships are those (in any amount) that may create a conflict of interest and occur within the 12'months preceding and during the time that the individual is engaged in writing the article. All reported conflicts are thoroughly managed in order to ensure any potential bias within the content is eliminated. However, if you'perceive a bias within the article, please report the circumstances on the evaluation form.

Please note we have advised the authors that it is their responsibility to disclose within the article if they are describing the use of a device, product, or drug that is not FDA approved or the off-label use of an approved device, product, or drug or unapproved usage.

Disclosures of Significant Relationships with Relevant Commercial Companies/Organizations by the Editorial Staff

Ernest E. Moore, Editor: PI, research support and shared U.S. patents Haemonetics; PI, research support, TEM Systems, Inc. Ronald V. Maier, Associate editor: consultant, consulting fee, LFB Biotechnologies. Associate editors: David Hoyt and Steven Shackford have nothing to disclose. Editorial staff: Jennifer Crebs, Jo Fields, and Angela Sauaia have nothing to disclose."

Author Disclosures

The authors have nothing to disclose.

Reviewer Disclosures

The reviewers have nothing to disclose.

Cost

For AAST members and *Journal of Trauma and Acute Care Surgery* subscribers there is no charge to participate in this activity. For those who are not a member or subscriber, the cost for each credit is $25.

System Requirements

The system requirements are as follows: Adobe® Reader 7.0 or above installed; Internet Explorer® 7 and above; Firefox® 3.0 and above, Chrome® 8.0 and above, or Safari™ 4.0 and above.

Questions

If you have any questions, please contact AAST at 800-789-4006. Paper test and evaluations will not be accepted.

Submitted: August 22, 2016, Revised: November 16, 2016, Accepted: December 6, 2016, Published online: December 28, 2016.
From the Center for Clinical Effectiveness, Office of the Chief Quality Officer (G.O.G., S.S.), Baylor Scott & White Health, Dallas, TX; and Center for Surgery and Public Health, Department of Surgery (A.H.), Brigham and Women's Hospital, Boston, MA.
This study was presented at the75th annual meeting of the American Association for the Surgery of Trauma, September 14–17, 2016, in Waikoloa, Hawaii.
Address for reprints: Shahid Shafi, MD, MPH, FACS, 8080 North Central Expressway, Suite 500, Dallas, TX 75026; email: shahid.shafi@bswhealth.org.

DOI: 10.1097/TA.0000000000001355

BACKGROUND: Higher volume has been associated with lower mortality for several surgical diseases. It is not known if this relationship exists in the management of Emergency General Surgery (EGS). Our hypothesis was that EGS patients treated at hospitals with higher EGS volume experienced lower mortality rates than those treated at low-volume hospitals.

METHODS: This was a retrospective analysis of 2010 National Inpatient Sample data, maintained by the Agency for Healthcare Quality and Research as a representative national sample of inpatients. Patients with EGS diseases were identified using American Association for the Surgery of Trauma definitions using ICD-9 codes (2,640,725 patients from 943 hospitals). Multivariable hierarchical logistic regression model was used to estimate the risk-standardized mortality rate (RSMR) for each hospital, adjusted for patient (age, sex, race, ethnicity, insurance type, socioeconomic status, comorbidities) and hospital (region, location, bed size, teaching status, ownership) characteristics. A cubic spline regression model with 4 knots was used to identify the volume associated with low mortality rates.

RESULTS: The volume of EGS patients treated was inversely associated with hospital mortality rate. RSMR in hospitals in the highest quintile of volume (median, 7424 patients) was 1.62% (95% CI: 1.61–1.64%); at hospitals in the lowest quintile of volume (median, 68 patients), it was 6.1% (95% CI: 6.0–6.2%) ($p < 0.0001$). Mortality rate stabilized at an annual volume of 688 (95% CI: 554–753) patients. The mortality rate in hospitals that treated fewer than 688 patients was 5.0% (95% CI: 4.8–5.1%), compared to 1.99% (95% CI: 1.96–2.01%) at those that treated 688 or more patients ($p < 0.0001$).

CONCLUSION: EGS patients treated at hospitals with a higher volume of EGS patients experienced lower mortality rates, with a possible threshold of 688 patients per year. A regionalized system of EGS care where complex patients are treated at large-volume centers may improve patient outcomes. (*J Trauma Acute Care Surg.* 2017;82: 497–504. Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic study, level III.

KEY WORDS: Emergency general surgery; regionalization; high-volume hospitals; mortality.

Previous studies have shown an inverse relationship between surgical volume and outcomes, indicating that, for several surgical procedures, higher volume of surgical cases is associated with lower mortality.[1–5] For example, in the case of Whipple procedure (pancreaticoduodenectomy), lower rates of inpatient mortality have been reported in medium- and high-volume hospitals as compared to low-volume hospitals.[6] A similar inverse volume-outcome relationship has been reported for esophageal resection, liver resection, gastric bypass, aneurysm, and cancer-related conditions.[6–16] In fact, some recent reviews have suggested that thousands of preventable surgical deaths occur each year in the United States because high-risk elective surgeries are performed in hospitals with inadequate experience of the surgical procedure involved.[1,3–5] As a result, accreditation processes for certain specialty surgical centers, such as trauma[17] and bariatric surgery,[18] have minimum volume requirements.

The relationship between volume and outcomes of emergency general surgery (EGS) patients is not known. A recently developed definition of EGS by the American Association for the Surgery of Trauma (AAST) has enabled new research in this field.[19–22] Currently, EGS patients are treated at almost all acute care hospitals across the country, with little information on their outcomes. The purpose of this study was to measure the association between hospitals' volume of EGS patients and their in-hospital mortality rates. The study hypothesis was that patients treated at hospitals with higher volume of EGS patients will experience lower mortality rates.

METHODS

This is a retrospective analysis of the National Inpatient Sample (NIS) data for 2010. The NIS database is part of the Health Care Utilization Project (HCUP), maintained by the Agency for Healthcare Research and Quality (AHRQ).[23] It provides a representative national sample of inpatients and provides sampling weights that can be used to estimate nationwide incidence of diseases.

The study population consisted of EGS patients in the NIS 2010 database that were identified by AAST criteria for EGS diseases using the primary ICD-9-CM diagnosis codes.[22] Individual ICD-9-CM diagnoses were then grouped into 31 EGS diseases, namely abdominal pain, appendix, bowel ischemia, breast infection, Clostridium difficile, colorectal cancer, diverticular disease, empyema chest, enteric fistula, enteritis, esophagus, gastrointestinal bleed, gall bladder, hemorrhoids, hernia, intestinal obstruction, liver, meckles diverticulum, pancreatitis, peptic ulcer disease, perianal, peritonitis and abscess, pneumothorax, retroperitoneal infection and abscess, shock, small intestine cancer, soft tissue infection, stoma, support devices, vascular, and wounds.

The number of patients with these diagnoses treated at each hospital annually was calculated using sampling discharge weights provided by NIS. Hospitals were then divided into 5 quintiles based upon their volume of EGS patients. Hospital characteristics, including geographic region (Midwest, Northeast, South, and West), location (rural vs. urban), teaching status (teaching vs. non-teaching), ownership (government, private investor-owned, and private not-for-profit), and bed size (large, small, and medium), were obtained from NIS. Hospital bed size was based on the number of beds and was specific to hospital's region, location, and teaching status.[23] For example, an urban-teaching hospital with at least 425 in the Northeast was classified as a large hospital, whereas in the West, the threshold for an urban-teaching hospital was at least 325 hospitalizations.

We calculated the hospital-specific risk-standardized mortality rate (RSMR) to investigate the volume-mortality relationship of patients with EGS. This analysis has been applied widely for profiling hospitals on patients' outcomes[24,25] and is extensively used by the Centers for Medicare and Medicaid Services (CMS).[26] We modeled mortality using weighted hierarchical logistic regression model. Hospitals were included as

random intercept effect to account for within-hospital clustering of patients. Fixed-effect independent variables included age, sex, race, ethnicity, social economic status (SES, based upon median household income quartile by patient's zip code provided in NIS), insurance, need for an operative procedure, indicator of transfer-in, comorbidities using Charlson Comorbidity Index,[27] and hospital characteristics including location, region, teaching status, bed size, and ownership. The "expected" mortality for each hospital was estimated using the model described above and the average hospital-specific effect, i.e., the average effect among all hospitals in the sample. The "predicted" mortality for each hospital was estimated given the same patient mix but an estimated hospital-specific effect. We then calculated hospital-specific RSMR as the ratio of a hospital's "predicted" number of deaths to the "expected" number of deaths, multiplied by the national observed EGS mortality rate.

Within-hospital clustering effects were assessed using intraclass correlation coefficient (ICC). This measures the proportion of variance in outcome (mortality) explained by the grouping of patients within hospitals.[28] We obtained an ICC of 0.137 from the random intercept facility model, which indicated that approximately 13.7% of the variability in mortality was accounted for by the clustering effect within hospitals in our study.

The model predictive accuracy was evaluated using area under the receiver operating characteristic (ROC) curve (c-statistic). We obtained a c-statistic of 0.784 (95% CI, 0.780–0.788), which indicated that the discrimination ability of our model was good. Hosmer-Lemeshow goodness-of-fit (HL-GOF) test was used to assess model calibration. The HL-GOF test was statistically significant (χ^2 = 1,529, df = 8, $p < 0.0001$), suggesting poor fit of the model. However, this is a common occurrence in studies with large sample sizes such as the present study and has little effect on the validity of the model.

The relationship between RSMR and annual EGS volume for each hospital was depicted in a scatter plot. We assessed volume-mortality relationship from fitting a weighted cubic spline regression model with 4 knots.[29] The coefficient of determination (r-squared) was used to assess how close the data fitted the cubic spline regression curve. We obtained an r-squared of 0.450 for the fitted cubic spline regression curve, indicating that hospital volume explained about 45% of the total variation in EGS mortality rate.

The fitted cubic spline curve was assessed to determine the volume threshold at which RSMR stabilized with increasing hospital volume. This was achieved by calculating slopes at different points of the cubic spline regression curve and considering the index point from a streak of points with minimum slope. Confidence intervals on volume threshold was obtained from 1,000 bootstrap samples.[30]

Data were analyzed using SAS version 9.4 (SAS Institute, Cary, NC) and R,[31] with two-tailed p values <0.05 considered statistically significant.

TABLE 1. Summary of Hospital Characteristics by Hospital Volume Quintiles for EGS Patients in NIS 2010 Data

		Hospital Volume				
Characteristics	**All**	**1 (Lowest)**	**2**	**3**	**4**	**5 (Highest)**
No. hospitals	943	188	189	188	189	189
Hospital volume						
Range	4–23,561	4–175	177–858	869–2,392	2,395–4,880	4,896–23,561
Median (IQR)	1,357 (249–4,301)	67 (27–117)	393 (249–554)	1,356 (1,086–1,969)	3,519 (2,866–4,296)	7,424 (6,040–9,694)
Region—n (%)						
Midwest	273 (29.0)	75 (39.9)	68 (36.0)	57 (30.3)	46 (24.3)	27 (14.3)
Northeast	123 (13.0)	5 (2.7)	14 (7.4)	22 (11.7)	32 (16.9)	50 (26.5)
South	365 (38.7)	74 (39.4)	68 (36.0)	79 (42.0)	71 (37.6)	73 (38.6)
West	182 (19.3)	34 (18.1)	39 (20.6)	30 (16.0)	40 (21.2)	39 (20.6)
Location*—n (%)						
Rural	385 (40.8)	135 (71.8)	128 (67.7)	90 (47.9)	28 (14.8)	4 (2.1)
Urban	548 (58.1)	53 (28.2)	58 (30.7)	96 (51.1)	158 (83.6)	183 (96.8)
Teaching status*—n (%)						
Nonteaching	755 (80.1)	176 (93.6)	179 (94.7)	172 (91.5)	139 (73.5)	89 (47.1)
Teaching	178 (18.9)	12 (6.4)	7 (3.7)	14 (7.4)	47 (24.9)	98 (51.9)
Ownership*—n (%)						
Government, nonfederal	204 (21.6)	76 (40.4)	53 (28.0)	28 (14.9)	21 (11.1)	26 (13.8)
Private, investor-owned	154 (16.3)	27 (14.4)	22 (11.6)	48 (25.5)	35 (18.5)	22 (11.6)
Private, nonprofit	575 (61.0)	85 (45.2)	111 (58.7)	110 (58.5)	130 (68.8)	139 (73.5)
Bed size*—n (%)						
Large	315 (33.4)	10 (5.3)	23 (12.2)	70 (37.2)	76 (40.2)	136 (72.0)
Medium	233 (24.7)	16 (8.5)	46 (24.3)	59 (31.4)	69 (36.5)	43 (22.8)
Small	385 (40.8)	162 (86.2)	117 (61.9)	57 (30.3)	41 (21.7)	8 (4.2)

*Characteristics for 10 hospitals were missing in NIS database; hence, the total number of hospitals for these characteristics is 933.

RESULTS

A total of 2,640,725 patients with EGS conditions were treated at 943 hospitals in the 2010 NIS database. The majority of the patients were 40 years or older (67%), female (54%), of White race (63%), and of non-Hispanic ethnicity (89%). Most of the patients were treated at hospitals that were large (62%), urban (87%), non-teaching (58%), and privately owned not-for-profit (72%). The number of EGS admissions per hospital ranged from 4 to 23,541 with a median of 1,357 patients (IQR 249–4,301) (Table 1).

Of the 943 hospitals, 248 (26%) reported no deaths and were included in the analysis. These hospitals were predominantly small (80%) and rural (68%). The 5 most common EGS conditions in these hospitals were soft tissue infection (20.7%), pancreatitis (12.2%), intestinal obstruction (11.7%), gall bladder (11.5%), and abdominal pain (7.9%).

The volume of EGS patients treated at hospitals was inversely associated with RSMR (Fig. 1). The average RSMR in hospitals in the highest quintile for volume (median 7,424 patients) was 1.63% (95% CI 1.61–1.65%) as compared to those in the lowest quintile for volume (median 67 patients) at 6.1% (95% CI 6.0–6.2%) with $p < 0.0001$ (Fig. 2). In fact, the RSMR dropped rapidly from the lowest to the next quintile of hospitals, then steadily improved up to the highest quintile.

The fitted cubic spline curve showed that RSMR stabilized at an annual hospital volume of 688 EGS patients (95% CI 554–753). The average RSMR in hospitals that treated fewer than 688 patients was 5.0% (95% CI 4.8–5.1%) as compared to those that treated 688 or more patients (1.99%; 95% CI 1.96–2.01%) with $p < 0.0001$. Applying the RSMR from hospital with EGS volume ≥688 patients per year to hospitals with lower volume, we estimate that of the total 933 deaths that occurred at low-volume hospitals, 220 deaths (23.5%) were potentially preventable if these patients were treated at hospitals that cared for 688 or more EGS patients.

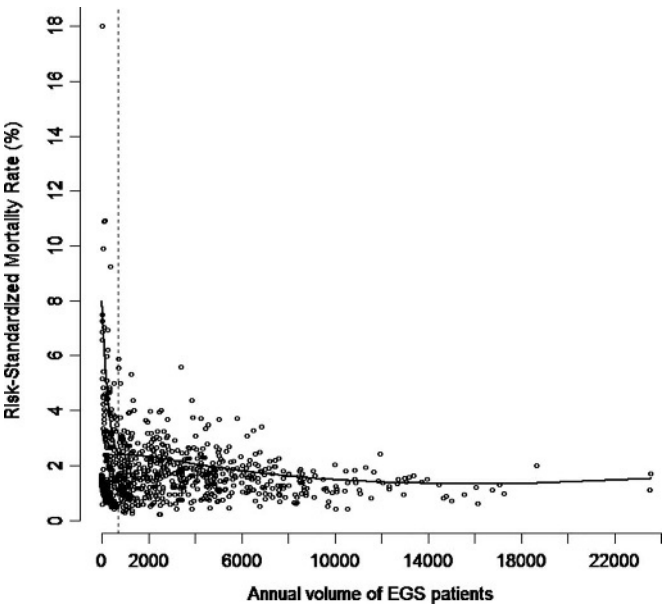

Figure 1. Relationship between annual volume of emergency general surgery (EGS) patients at hospitals and their risk-standardized mortality rate. Dotted line represents an annual volume of 688 patients at which the mortality rate stabilized.

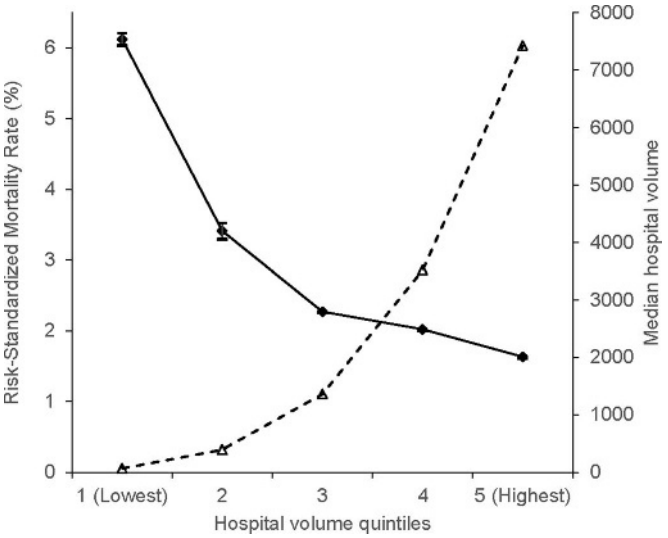

Figure 2. Risk-standardized mortality rate with 95% confidence interval and median hospital volume (triangular symbol) by quintile of volume of emergency general surgery (EGS) patients at hospitals.

DISCUSSION

This is the first study to measure volume-outcome relationship in EGS patients and confirms the existence of an inverse relationship, which is consistent with other surgical diseases. In this large national sample, we have found that hospitals with higher annual volume of EGS patients have lower mortality rates than hospitals with lower volumes of EGS patients. The results are particularly striking when comparing lowest quintile volume hospitals to highest quintile volume hospitals where the adjusted mortality rate drops threefold, from 6.1% to 1.6%. Our analysis also suggests an optimal volume threshold of 688 EGS patients annually that is associated with lower in-hospital mortality rate.

The findings are consistent with those of other studies that have reported an inverse relationship between volume and mortality for other surgical procedures. A study by Begg et al. on selected oncology procedures reported that higher hospital volume was linked with lower mortality for pancreatectomy, esophagectomy, liver resection, and pelvic exenteration.[7] The most striking results were observed for esophagectomy, where operative mortality was 17.3% in low-volume hospitals as compared to 3.4% in high-volume hospitals. Another study by Reames et al. also found a strong inverse relationship between hospital volume and mortality.[32] Hence, it is not surprising to find a similar relationship in EGS patients.

Although the reasons for better outcomes with higher volume are not clear, it is likely a combination of availability of appropriate personnel, optimal resources, standardized processes of care, and institutional experience. In other words, a

center caring for a high volume of patients with a particular disease tends to develop an expertise in caring for such patients. Such institutions also provide a model for other hospitals that aspire to acquire expertise in the treatment of specific conditions.

The inverse relationship between volume and outcome is so well established that it is routinely used as a criterion by organizations that accredit centers of excellence. For example, designation of a Level I trauma center requires a minimum of 1,200 cases per year whereas centers for metabolic and bariatric surgery are required to perform a minimum of 50 stapling procedures per year to be designated Comprehensive Centers.[17,33] Similarly, the Joint Commission has minimum volume requirements for several disease-specific care certification programs.[34] For example, the Comprehensive Stroke Center Certification program requires a hospital to treat a minimum average of volume of 20 subarachnoid hemorrhages, perform a minimum of 15 combined clipping/coiling procedures, and administer at least 25 intravenous tissue plasminogen activator treatments annually for patients with ischemic stroke.[35] Interestingly, our finding of 688 patients as a threshold is similar to that reported by Nathens et al. for trauma centers.[36]

Currently, there is no such requirement for hospitals providing EGS care. In fact, every acute care hospital with general surgeons on staff is expected to provide EGS care. Our findings suggest that establishing minimum volume requirements for hospitals providing EGS care has the potential to improve patient outcomes and reduce mortality. We estimate this threshold to be about 688 patients per year. However, a confounding factor is the inability of this analysis to provide volume thresholds for specific diseases or diseases with different severities. For example, it is possible that there is no volume threshold for simple appendectomies, but there may be one for necrotizing fasciitis involving a large body surface area. At the present time, these disease-specific thresholds have not been established. However, this is similar to trauma center designation criteria that do not require injury-specific volume.

An important implication of our findings is the issue of regionalization of EGS care. It is unrealistic to expect all hospitals to be able to care for all EGS patients at all times, irrespective of the complexity of care that may be needed. Hence, the logical answer will be to have a tiered regionalized system of care, depending upon the availability of resources. For example, a patient with necrotizing soft tissue infection involving a large surface area presents with septic shock to a small rural hospital. This hospital may have the capability to initiate fluid resuscitation, start intravenous antibiotics, and undertake the initial debridement. However, the patient may be better off at a larger regional hospital where he/she may receive critical care, repeated debridement, complex wound care, and treatment for multidrug-resistant organisms. This is the same approach that is currently used by regional trauma systems wherein hospitals are designated as Level I through IV, depending upon the availability of resources.

The study has a few limitations that should be recognized. It is a retrospective analysis of an administrative database with all its inherent limitations. NIS consists of administrative data captured at discharge and not clinical data. Also, each record in the NIS database represents one hospitalization. Hence, it is possible for an EGS patient to contribute to multiple hospitalizations if, for example, the patient was transferred to another hospital and both hospitals are sampled in NIS.[37] There are no patient identifiers in NIS, and hence, it is not possible to link them. Another limitation of the data used in this analysis is that it only captures in-hospital mortality. Hence, our findings likely underestimate mortality rates where a patient expires after being discharged from the hospital. A study that evaluated the relationship between hospital volume and 30-day postoperative mortality among cancer surgery patients found the relationship still exists.[7] Also, as mentioned previously, an important limitation of the optimal volume threshold of 688 annual EGS patients to achieve lowest mortality is based upon all EGS conditions combined. However, there are significant differences in complexity of care required for specific conditions that constitute EGS. Hence, no inferences should be derived about optimal volume threshold for specific conditions. We were unable to develop reliable estimates for specific diseases because of the small number estimation problem.

CONCLUSION

In conclusion, we found that EGS patients treated at hospitals with higher volume of EGS patients experienced lower mortality rates, with a possible threshold of 688 patients per year. The findings suggest the existence of a gap in quality of care between high- and low-volume hospitals. One option to bridge this gap may be to develop a regionalized system of EGS care where complex and high-risk patients are treated at large-volume centers. However, further research is needed to identify specific patients who may benefit from such care.

AUTHORSHIP

G.O. contributed to the literature search, study design, data collection, data analysis, data interpretation, writing, and critical revision. A.H. contributed to the data interpretation, writing, and critical revision. S.S. contributed to the study design, data analysis, data interpretation, writing, and critical revision.

DISCLOSURE

The author declares no conflicts of interest.

REFERENCES

1. Birkmeyer JD, Stukel TA, Siewers AE, Goodney PP, Wennberg DE, Lucas FL. Surgeon volume and operative mortality in the United States. *N Engl J Med*. 2003;349(22):2117–2127.
2. Flood AB, Scott WR, Ewy W. Does practice make perfect? Part I: the relation between hospital volume and outcomes for selected diagnostic categories. *Med Care*. 1984;22(2):98–114.
3. Flood AB, Scott WR, Ewy W. Does practice make perfect? Part II: the relation between volume and outcomes and other hospital characteristics. *Med Care*. 1984;22(2):115–125.
4. Hannan EL, O'Donnell JF, Kilburn H Jr, Bernard HR, Yazici A. Investigation of the relationship between volume and mortality for surgical procedures performed in New York State hospitals. *JAMA*. 1989;262(4):503–510.
5. Hannan EL, Radzyner M, Rubin D, Dougherty J, Brennan MF. The influence of hospital and surgeon volume on in-hospital mortality for colectomy, gastrectomy, and lung lobectomy in patients with cancer. *Surgery*. 2002; 131(1):6–15.
6. Ho V, Heslin MJ. Effect of hospital volume and experience on in-hospital mortality for pancreaticoduodenectomy. *Ann Surg*. 2003;237(4):509–514.
7. Begg CB, Cramer LD, Hoskins WJ, Brennan MF. Impact of hospital volume on operative mortality for major cancer surgery. *JAMA*. 1998;280(20): 1747–1751.

8. Borowski DW, Bradburn DM, Mills SJ, Bharathan B, Wilson RG, Ratcliffe AA, Kelly SB; Northern Region Colorectal Cancer Audit Group (NORCCAG). Volume-outcome analysis of colorectal cancer-related outcomes. *Br J Surg*. 2010;97(9):1416–1430.
9. Damhuis RA, Meurs CJ, Dijkhuis CM, Stassen LP, Wiggers T. Hospital volume and post-operative mortality after resection for gastric cancer. *Eur J Surg Oncol*. 2002;28(4):401–405.
10. Glasgow RE, Showstack JA, Katz PP, Corvera CU, Warren RS, Mulvihill SJ. The relationship between hospital volume and outcomes of hepatic resection for hepatocellular carcinoma. *Arch Surg*. 1999;134(1):30–35.
11. Modrall JG, Rosero EB, Smith ST, Arko FR 3rd, Valentine RJ, Clagett GP, Timaran CH. Effect of hospital volume on in-hospital mortality for renal artery bypass. *Vasc Endovascular Surg*. 2009;43(4):339–345.
12. van Lanschot JJ, Hulscher JB, Buskens CJ, Tilanus HW, ten Kate FJ, Obertop H. Hospital volume and hospital mortality for esophagectomy. *Cancer*. 2001; 91(8):1574–1578.
13. Funk LM, Gawande AA, Semel ME, Lipsitz SR, Berry WR, Zinner MJ, Jha AK. Esophagectomy outcomes at low-volume hospitals: the association between systems characteristics and mortality. *Ann Surg*. 2011;253(5): 912–917.
14. Markar SR, Karthikesalingam A, Thrumurthy S, Low DE. Volume-outcome relationship in surgery for esophageal malignancy: systematic review and meta-analysis 2000–2011. *J Gastrointest Surg*. 2012;16(5):1055–1063.
15. Chang AC, Birkmeyer JD. The volume-performance relationship in esophagectomy. *Thorac Surg Clin*. 2006;16(1):87–94.
16. Troëng T. Volume versus outcome when treating abdominal aortic aneurysm electively—is there evidence to centralise? *Scand J Surg*. 2008;97(2): 154–159; discussion 9–60.
17. American College of Surgeons (ACS). VRC Criteria Type I and Type II for Level I Trauma Centers. Available at: https://www.facs.org/.../trauma/vrc/outcomes. Accessed July 18, 2016.
18. Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP). Resources for Optimal Care of the Metabolic and Bariatric Surgery Patient. 2016. Available at: https://www.facs.org/quality%20programs/mbsaqip/standards. Accessed July 18, 2016.
19. Ogola GO, Gale SC, Haider A, Shafi S. The financial burden of emergency general surgery: national estimates 2010 to 2060. *J Trauma Acute Care Surg*. 2015;79(3):444–448.
20. Ogola GO, Shafi S. Cost of specific emergency general surgery diseases and factors associated with high-cost patients. *J Trauma Acute Care Surg*. 2016; 80(2):265–271.
21. Gale SC, Shafi S, Dombrovskiy VY, Arumugam D, Crystal JS. The public health burden of emergency general surgery in the United States: a 10-year analysis of the Nationwide Inpatient Sample—2001 to 2010. *J Trauma Acute Care Surg*. 2014;77(2):202–208.
22. Shafi S, Aboutanos MB, Agarwal S Jr, Brown CV, Crandall M, Feliciano DV, Guillamondegui O, Haider A, Inaba K, Osler TM, Ross S, Rozycki GS, Tominaga GT. AAST Committee on Severity Assessment and Patient Outcomes. Emergency general surgery: definition and estimated burden of disease. *J Trauma Acute Care Surg*. 2013;74(4):1092–1097.
23. Agency for Healthcare Research and Quality Healthcare Cost and Utilization Project (HCUP). Introduction to the HCUP nationwide Inpatient Sample (NIS). 2010. Available at: http://www.hcup-us.ahrq.gov. Accessed July 18, 2016.
24. The COPSS-CMS White Paper Committee: Ash AS, Fienberg SE, Louis TA, Normand SLT, Stukel TA, Utts J. Statistical Issues in Assessing Hospital Performance: Commissioned by the Committee of Presidents of Statistical Societies (2012). Available at: https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/HospitalQualityInits/Downloads/Statistical-Issues-in-Assessing-Hospital-Performance.pdf. Accessed November 11, 2016.
25. Normand SLT, Shahian DM. Statistical and clinical aspects of hospital outcomes profiling. *Statistical Science*. 2007;22(2):206–226.
26. Centers for Medicare & Medicaid Services. 2016 AMI, HF, Pneumonia, COPD, and Stroke Mortality Measures Updates and Specifications Report. Available at: http://www.qualitynet.org. Accessed November 11, 2016.
27. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40(5):373–383.
28. Hox J. *Multilevel Analysis: Techniques and Applications*. New York: Taylor & Francis Group; 2002.
29. Harrell FE. *Regression Modeling Strategies with Applications to Linear Models, Logistic Regression, and Survival Analysis*. New York: Springer-Verlag; 2001.
30. Efron B, Tibshirani RJ. *An Introduction to the Bootstrap*. Chapman & Hall Boca Raton, FL; 1993.
31. R Development Core Team. A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2010.
32. Reames BN, Ghaferi AA, Birkmeyer JD, Dimick JB. Hospital volume and operative mortality in the modern era. *Ann Surg*. 2014;260(2):244–251.
33. Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP). Resources for Optimal Care of the Metabolic and Bariatric Surgery Patient. 2016. Available at: https://www.facs.org/quality%20programs/mbsaqip/standards. Accessed July 18, 2016.
34. Joint Commission Resources. The Disease-Specific Care Certification Manual (DSC). Available at: https://www.jointcommission.org/standards_information/dsc_requirements.aspx. Accessed July, 18 2016.
35. Joint Commission Resources. Certification Comprehensive Stroke Center. Available at: https://www.jointcommission.org/certification/advanced_certification_comprehensive_stroke_centers.aspx. Accessed July 18, 2016.
36. Nathens AB, Jurkovich GJ, Maier RV, Grossman DC, MacKenzie EJ, Moore M, et al. Relationship between trauma center volume and outcomes. *JAMA*. 2001;285(9):1164–1171.
37. Memtsoudis SG. Limitations associated with the analysis of data from administrative databases. *Anesthesiology*. 2009;111(2):449; author reply 50–1.

DISCUSSION

Dr. David B. Hoyt (Chicago, Illinois): The authors have presented, for the first time, an analysis of mortality in emergency general surgery broken down by hospital experience as reflected by the volume of cases seen. The rationale for this is quite obvious in that hospitals with greater experience would be the obvious place to send patients if emergency general surgery were regionalized.

On the surface, this seems intuitive and, in fact, is a natural extension of the trauma systems experience led by the members of the AAST and the American College of Surgeons' Committee on Trauma.

I do have a question with the analysis and, therefore, the conclusions. The analysis left out hospitals with no mortality. And, as the authors describe, a disproportionate number of these were in smaller hospitals.

This, presumably, would be hospitals with lower acuity disease but, still, these hospitals provide a vital service and access for rural communities, underserved areas, and the overall needs of the population.

My concern is that without these hospitals included the smaller hospitals are potentially biased regarding their performance. As such, I have several questions for the authors.

If you include all deaths and repeat the analysis do the results change? That is, by including both large hospitals and small hospitals with zero mortality, is the conclusion that higher volume hospitals have lower mortality still valid?

What is the breakdown by diagnosis of the difference in mortality between high volume and low volume hospitals? Talking about regionalization makes sense but only if there are specific diseases where regionalization may benefit the patient.

Without analysis of the types of patients where mortality differences are clearly seen, a public policy decision regarding regionalization would be very difficult to implement.

What are the unintended consequences of this type of analysis if they are not corrected for conditions where there are no differences?

This has great implications in terms of removing incentives for surgeons to staff smaller hospitals and, at the end of the day, there has to be a balance between regionalization and providing remote access.

The authors are, again, to be congratulated on taking on an important topic. I am sure that in the future regionalization of some of these conditions is inevitable, but we really need to be very careful about how we go about doing this.

Thank you, Dr. Shafi, for bringing this to our attention and thanks to the Association for the privilege of discussing this paper.

Dr. John F. Bilello (Fresno, California): I want to congratulate you on a very thoughtful paper. How does being a regionalized emergency general surgery center interface with also being a Level I trauma center? As you all know, they usually end up being one and the same and resources at trauma centers tend to be used up quickly just with trauma. Thank you.

Dr. Mark A. Malangoni (Philadelphia, Pennsylvania): I agree with a lot of what you have presented but echo many of Dr. Hoyt's cautions about extrapolating your findings to all emergency general surgery patients.

In essence what you showed in your conclusions was that complex emergency general surgery patients, perhaps, would benefit from going to a regionalized center with a higher volume of like patients, yet your data includes patients that don't have complex disease.

As a note of caution, when the ACS established trauma centers we didn't say that all injured patients needed to go to an established trauma center. There were criteria for transportation and transfer.

In addition, one of the bugaboos that we still are trying to sort out about trauma center deaths relates to patients who decide not to be transferred because they realize that the outcome of their care is going to be terrible no matter where they are cared for. The same goes for emergency general surgery patients. I don't believe you have any way of correcting for that issue.

So, this is a nice start. You need some more detail in order for us to accept the conclusions. Thank you.

Dr. Ajai K. Malhotra (Burlington, Vermont): I enjoyed that presentation. Having moved to a rural state I've seen firsthand that these smaller hospitals are dependent upon their surgical volume to be sustainable.

If we take away any of the surgical volume, the hospital almost goes out of business. And that has a broader impact of overall health care, not just surgical but otherwise as patients are less likely to make the trip to a distant place to get a colonoscopy or something like that.

So I think it's very important to know what the unintended consequences of such a change may be.

Dr. Marie M. Crandall (Jacksonville, Florida): Dr. Shafi, I want to congratulate you and the coauthors for an interesting and provocative paper.

The question is, are you simply demonstrating the differences between rural and urban presentation of disease? We know that for trauma, for example, mortality is at least doubled for rural trauma patients as they are for urban trauma patients.

Some of that has to do with distance but, also, I would say for emergency general surgery patients, the delay to presentation. Rural and urban populations are simply different. So is there a way to adjust for that or look at that in an analysis between hospitals?

Dr. Garth Utter (Sacramento, California): Provocative work, Shahid. Nice job with the analysis. Do you have more information on the time to mortality? And, also, despite all the limitations of administrative data you should have procedure day information. Do you have any information on the time to procedures?

Dr. Preston R. Miller (Winston-Salem, North Carolina): That was a great paper and I think the idea of regionalization makes a ton of sense. Some of my concerns echo the concerns of some of the other people that have mentioned important points.

So given that on the one hand regionalization seems to make a lot of sense and this does probably or at least for my external perception it fits into the trauma concept but on the other hand these regional hospitals are vital to the communities, they want some of these patients if not most of these patients and it's important for them to keep some of these patients from a health care standpoint, from an economic standpoint, what do we do next? What are your specific ideas for next, for moving on towards regionalization? Thank you.

Dr. Ronald I. Gross (Springfield, Massachusetts): We are in a unique position of being a major medical center in a relatively rural area. And so I really appreciate what you have done.

Drs. Malangoni and Malhotra have really nailed it, and I think what as we move forward the answer and the next step is going to see exactly which hospitals self-select their EGS patients.

The smaller hospitals who don't have an ICU or have anesthesia who is unwilling to put the patient to sleep for these procedures is going to self-select out those patients to be transferred to the regional tertiary care center.

The hospitals will be preserved but the EGS patients with the highest risk will likely be moved. I think the key here, though, is with the patients whose outcome is going to be the same regardless of where they go, i.e., they're going to die.

The goals of care must be discussed with the patient and their caregivers and the families prior to the decision to make the transfer. So I think we have a whole lot of stuff that has to be discussed. And I think your paper is going to start that discussion. Thank you very much.

Dr. James M. Betts (Oakland, California): Children's hospitals tend to be mission-based and safety-net institutions. As such, whether they're complex, really ill children, we tend to accept everyone. I think this concept is very important. We do want to maintain quality of care and the best outcome.

But I'm just wondering is there going to be some screening process or will that factor into these specialized centers accepting or not accepting an adult patient or a pediatric patient, dependent on stratification, perhaps, because of their insurance status?

In California, virtually every child is at least covered by MediCal, whether you are born there, or you just come into the state two minutes beforehand. But I'm just fearful that with all these other comments of maintaining volume at some of these smaller hospitals the tendency might be to hold on to a patient

who is not a medically-indigent adult and then sending those other patients to these other centers.

I think it's just something that we will all have to continue to watch.

Dr. Shahid Shafi (Dallas, Texas): I wasn't around in the 1970s when the trauma center designation criteria were being discussed and the first optimal resources document for trauma was published. But I suspect a similar discussion happened at that time, similar to what we are witnessing here today. And I believe that this is an historic time in the care of our EGS patients where we are asking these kinds provocative, policy questions.

The goal of our analysis is to improve the care of our patients. We are not saying that volume is the only reason for poor outcomes, but volume is certainly a representation of some quality of care that was missing.

What will be the policy implication if we have designated EGS centers? What will be the financial implications? The implications for patients?

And the answer, as far as I can tell you right now, is I don't know. I don't know what the implications will be but what I know for sure is that there is a gap in quality that we need to bridge.

This is my personal opinion. It does not reflect the opinion of the Association or the Patient Assessment Committee, it is my personal opinion that instead of talking about designation criteria and regionalization, we need to talk about is what are the optimal resources that every hospital caring for EGS patients should be able to provide?

How do we help those hospitals achieve those resources? How do we help them recognize their limitations? And how do we help them figure out where they will send the patient if they can't take care of them?

Dr. Hoyt asked about including hospitals with zero mortality. I'm happy to do that, although it makes me a little uncomfortable because this is the same problem we had with NTDB. There were hospitals that were not reporting any complications. In a lot of early analysis, we excluded them. Our concern is lack of reporting.

The next issue is disease by severity. Of course, we are not suggesting that every appendicitis should be transferred to a high volume EGS center but certainly the complicated patients should be. For example, a patient with necrotizing fasciitis who is going to require multiple take-backs to the OR and extended ICU care.

Dr. Utter asked about severity as APR/DRG severity grading system in NIS database. It is not included in this analysis.

John asked about interface between trauma and EGS, and the risk that EGS may consume all the trauma resources. I disagree with that assessment. In fact, I think the two are very complementary to each other. A trauma center that becomes an EGS center will have built-in capabilities for data collection, registry, performance improvement processes, and systematic evaluation of these patients.

Dr. Malhotra is concerned about diversion of surgical volume and its impact on the finances of the hospital. I believe it is a valid concern. There will be some unintended consequences. But we need to focus on providing optimal resources for the best care of the patients.

Dr. Crandall's asked about rural versus urban differences. It was included in the risk-adjustment model but we haven't tried to look at specific differences.

Dr. Utter asked about time to death analysis. We don't have the time to death in NIS database. Time to procedure is there but we did not look at specific operative procedures.

Dr. Gross and Dr. Betts were concerned about high-risk self-selection and selection based on insurance and uninsured patients being transferred to large volume centers. Those are the similar discussions we have had for trauma patients. And I think time will tell how that works out.

Dr. Miller and a lot of other people asked what are the next steps. I would say the next step is to determine what are the optimal resources that every hospital that is taking care of EGS patients should have in place.

And then we need to figure out if it reasonable to expect all hospitals to have all the resources available 24-hours a day or should there be some kind of a regionalized system.

Thank you very much for the privilege of the podium.