High-volume hospitals are associated with lower mortality among high-risk emergency general surgery patients

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INTRODUCTION: We have previously demonstrated that Emergency General Surgery (EGS) patients treated at high-volume hospitals experience lower mortality rates than those treated at low-volume hospitals. However, EGS comprises a wide spectrum of diseases. Our goal was to determine which EGS diseases had better outcomes at high-volume hospitals.

METHODS: We undertook a retrospective analysis of the National Inpatient Sample database for 2013 (a nationwide representative sample). Patients with EGS diseases were identified using American Association for the Surgery of Trauma definitions. A hierarchical logistic regression model was used to measure risk-adjusted probability of death, adjusting for age, sex, race, ethnicity, insurance type, and comorbidities. Patients were then grouped into 16 risk groups based upon their predicted probability of death. We then compared observed mortality rates at high- versus low-volume hospitals within each risk group.

RESULTS: Nationwide, 3,006,615 patients with EGS diseases were treated at 4,083 hospitals in 2013. Patients with predicted risk of death of 4% or higher (275,615 patients, 9.2%) had lower observed mortality rates at high-volume hospitals than at low-volume hospitals (7.7% vs. 10.2%, $p < 0.001$). We estimated that 1,002 deaths were potentially preventable if high-risk patients who were treated at low-volume hospitals were instead transferred to high-volume hospitals.

CONCLUSION: EGS patients with predicted risk of death of 4% or higher experience lower mortality rates at high-volume hospitals than at low-volume hospitals. A regional system of EGS care that enables rapid transfer of high-risk patients to high-volume hospitals may prevent several deaths. (*J Trauma Acute Care Surg.* 2018;85: 560–565. Copyright © 2018 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic and epidemiological, level III; Therapeutic/Case Management, level IV.

KEY WORDS: Emergency general surgery; high-risk patients; patient transfer; triage; regional systems of care.

Emergency General Surgery (EGS) is increasingly recognized as a distinct clinical entity, largely because of the efforts by the American Association for the Surgery of Trauma (AAST) over the last decade. In 2014, AAST published a definition of EGS diseases using practice-based data from several large medical centers in the USA.[1] Using this definition, we have estimated the annual volume of EGS patients requiring hospitalizations at 2.6 million, treated at hundreds of hospitals across the nation, with an annual cost exceeding $28 billion.[2,3]

At the present time, all acute care hospitals with a general surgeon on staff are expected to be able to care for a full spectrum of EGS patients. However, the quality of care at individual hospitals remains unknown as there are no standards for resources required for optimal care of EGS patients and no well-defined quality metrics. However, significant variations in risk-adjusted morality rates of EGS patients across hospitals based on patient volume have recently been reported, which underscores the need to establish an Emergency General Surgery Quality Improvement Program for benchmarking of hospitals.[4] This approach has been used successfully in the National Surgical Quality Improvement Program and Trauma Quality Improvement Program.[5–8] EGS patients treated at hospitals with high volumes experience lower mortality rates, which is similar to what has been observed in other specialties. Specifically, EGS patients treated at hospitals with 668 or more EGS patients annually experienced lower death rates than patients who were treated at hospitals with lower volumes of EGS patients.[9] The main difference between EGS patients and other types of surgical patients is that EGS patients represent a large spectrum of diseases and disease severity. Given the variety of diseases and variations in outcomes across hospitals, it has not been obvious which EGS patients will benefit from transfer to a high-volume hospital. At the present time, there are no regionalized systems of care for EGS, no formal mechanisms for transfers across hospitals, and no data-driven definitions of high-risk EGS patients.

The purpose of this study was to identify EGS patients who may benefit from transfer to hospitals that treat high volumes of EGS patients. We hypothesize that EGS patients at the highest risk of death will have better outcomes at high-volume hospitals than at low-volume hospitals.

METHODS

This was a retrospective analysis of hospital discharge data of patients who were treated for EGS diseases in 2013 in the Health Care Utilization Project National Inpatient Sample (NIS) dataset. The dataset is maintained by the Agency for Healthcare Research and Quality and represents a 20% stratified sample of inpatient discharges from US acute care hospitals.[10] NIS provides sample weights that enable researchers to estimate national rates.

Patients with EGS diseases were identified using the AAST definition for EGS diseases based upon the International Classification of Diseases, Ninth Revision (ICD-9) codes for the primary diagnosis.[1] Patient and hospital characteristics including age, sex, race, comorbidities, payer type, hospital region, location, teaching status, bed size, and ownership were obtained from NIS. Primary EGS diagnosis were grouped into 35 major disease categories (in alphabetical order): abdominal aneurysm, abdominal pain, appendix, bowel ischemia, breast infection, Clostridium difficile, colorectal cancer, diverticular disease, empyema chest, enteric fistula, enteritis, esophagus, extremity thromboembolism, gall bladder, gastrointestinal bleeding, hemorrhoids, hernia, intestinal obstruction, liver, Meckle's diverticulum, pancreatitis, perforation of intestine, peptic ulcer disease, perianal, peritonitis and abscess, pneumothorax, retroperitoneal infection and

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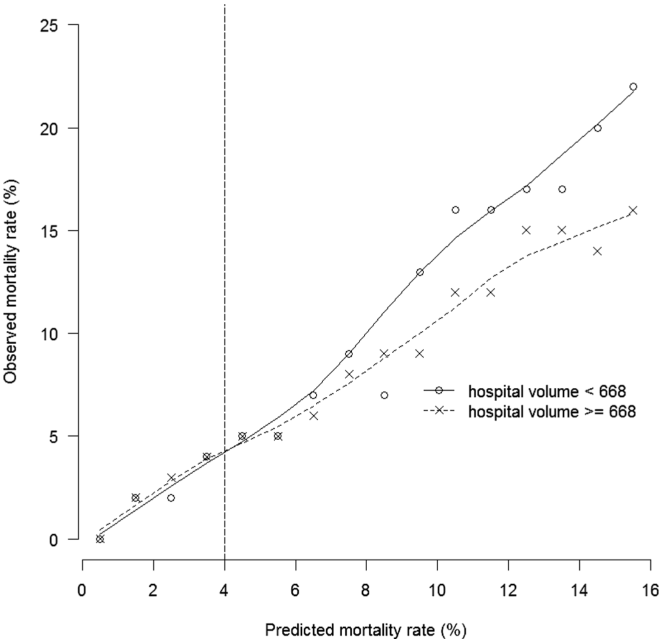

Figure 1. Plot of observed versus risk-adjusted probability of death for EGS patients in NIS 2013. Dashed lines indicate fitted smooth line for hospitals with EGS volume of ≥668 per year whereas solid line indicates fitted smooth line for hospitals with EGS volume <668 per year. Vertical dashed line indicates 4% threshold at which mortality risk starts to significantly differ between low- and high-volume hospitals.

abscess, shock, small intestine cancer, soft tissue infection, stoma, support devices, thrombophlebitis, and wounds.[1,11]

The primary outcome of interest was in-hospital death. Secondary outcomes were complications during hospitalization and hospital length of stay. Complications were derived from the secondary ICD-9 diagnosis and procedures codes, and included pneumonia, pulmonary embolism, venous thrombosis requiring therapy, progressive renal insufficiency/acute renal failure requiring dialysis, urinary tract infection, sepsis, septic shock, myocardial infarction, intraoperative or postoperative cardiac arrest requiring cardiopulmonary resuscitation, stroke/cerebral vascular accident, wound disruption, surgical site infection, bleeding/hemorrhage, transfusion, mechanical ventilation, and other complications, which included complications related to colostomy and enterostomy, peritoneal abscess, postoperative shock, hemorrhage and hematoma complicating a procedure, accidental puncture or laceration during a procedure, persistent postoperative fistula, non-healing surgical wound, and other specified and unspecified complications not elsewhere classified.

We used a weighted hierarchical multivariable logistic regression model to determine the risk-adjusted probability of death for each patient. Patient and hospital characteristics included in the model consisted of age, sex, race, payer type, income (by zip code of residence), comorbidities (using Charlson Comorbidity Index),[12] EGS disease group, hospital location, region, teaching status, bed size, and ownership as fixed-effect independent variables, while hospital was included as random effect to account for high correlation within patients seen in

TABLE 1. Characteristics and Outcomes for Emergency General Surgery Patients Grouped by Threshold for Low and High Risk-Adjusted Probability of Death

	All Patients	Low-Risk Group (<4%)	High-Risk Group (≥4%)
Number of patients	3,006,615	2,731,000 (90.8)	275,615 (9.2)
Age, years—mean ± SD	59.0 ± 19.2	57.1 ± 18.7	78.1 ± 10.8
Female sex	1,589,020	1,453,200 (53.2)	135,820 (49.3)
Race			
White	2,006,410	1,801,495 (66.0)	204,915 (74.3)
Black	374,530	348,235 (12.8)	26,295 (9.5)
Hispanic	325,660	309,940 (11.3)	15,720 (5.7)
Other	300,015	271,330 (9.9)	28,685 (10.4)
Income quartile			
Q1—$1 to $38,999	846,550	767,220 (28.1)	79,330 (28.8)
Q2—$39,000 to $47,999	775,025	704,415 (25.8)	70,610 (25.6)
Q3—$48,000 to $62,999	714,895	652,905 (23.9)	61,990 (22.5)
Q4—$63,000 or more	601,905	543,530 (19.9)	58,375 (21.2)
Not reported	68,240	62,930 (2.3)	5,310 (1.9)
EGS hospital volume			
Low (<668 admissions per year)	506,085	465,355 (17.0)	40,730 (14.8)
High (≥668 admissions per year)	2,500,530	2,265,645 (83.0)	234,885 (85.2)
Insurance type			
Commercial	821,970	799,685 (29.3)	22,285 (8.1)
Medicaid	366,025	351,465 (12.9)	14,560 (5.3)
Medicare	1,413,535	1,186,795 (43.5)	226,740 (82.3)
No charge	33,730	33,495 (1.2)	235 (0.1)
Other	100,715	94,280 (3.5)	6,435 (2.3)
Self-pay	266,300	261,210 (9.6)	5,090 (1.8)
Not reported	4,340	4,070 (0.1)	270 (0.1)
Hospital bed size			
Large	1,726,565	1,556,450 (57.0)	170,115 (61.7)
Medium	837,170	763,370 (28.0)	73,800 (26.8)
Small	442,880	411,180 (15.1)	31,700 (11.5)
Hospital ownership			
Government, nonfederal	356,010	324,135 (11.9)	31,875 (11.6)
Private, investor-owned	442,255	404,405 (14.8)	37,850 (13.7)
Private, nonprofit	2,208,350	2,002,460 (73.3)	205,890 (74.7)
Hospital location and teaching status			
Rural	358,385	326,545 (12.0)	31,840 (11.6)
Urban non-teaching	1,251,325	1,145,545 (41.9)	105,780 (38.4)
Urban teaching	1,396,905	1,258,910 (46.1)	137,995 (50.1)
Hospital region			
Midwest	651,220	592,545 (21.7)	58,675 (21.3)
Northeast	619,095	557,710 (20.4)	61,385 (22.3)
South	1,142,165	1,037,025 (38.0)	105,140 (38.1)
West	594,135	543,720 (19.9)	50,415 (18.3)
Outcomes			
Mortality	42,945	20,735 (0.8)	22,210 (8.1)
Complications	773,240	634,340 (23.2)	139,090 (50.5)
Length of stay (days)—median (IQR)*	3 (2–6)	3 (2–5)	5 (3–9)

*Length of stay excludes patients who expired.

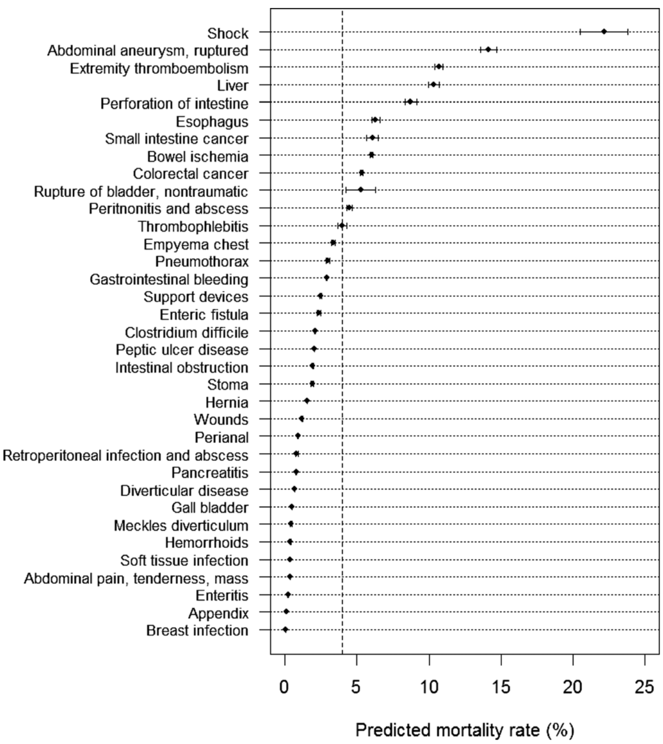

Figure 2. Predicted mortality rates (with 95% confidence intervals) for EGS disease. Vertical line indicates the 4% threshold for high risk of mortality.

the same hospital. We assessed the model performance and found it to have good discrimination ability with a c-statistic of 0.830 (95% CI 0.826 to 0.834).

Patients were then divided into 16 groups based upon their predicted probability of death, ranging from 0% to 15%, at intervals of 1%. Patients with probabilities of death exceeding 15% were combined into a single group. Within each risk group, we measured the observed death rates at high- versus low-volume hospitals. Hospitals were classified as high- versus low-volume using a threshold of 668 hospitalizations per year, based upon our previous work that showed the risk-adjusted mortality rate for all EGS patients was 2% at high-volume hospitals compared with 5% at low-volume hospitals.[9]

We plotted the observed death rates against the risk-adjusted death rates within each risk group and fitted two locally weighted scatter plot smoothing (Lowess) curves—one each for the high- and low-volume hospitals.[13] The level of risk at which the Lowess curves for high- and low-volume hospitals diverged was 4%. This was used as the threshold to identify patients at high risk of death. Based on this threshold, we classified EGS patients into two groups: high-risk group (if predicted probability of death ≥ risk threshold) and low-risk group (if predicted probability of death < risk threshold). We compared patient and hospital characteristics between the high- and low-risk groups of patients. We further computed mortality rates by EGS annual hospital volume and mortality risk threshold to determine the potential number of deaths that could have been prevented if high-risk patients treated at low-volume hospitals had instead been treated at high-volume hospitals. Lastly, we calculated the risk-adjusted probabilities of death, with 95% confidence intervals, for individual EGS disease categories to identify EGS diseases where risk of death exceeded the risk threshold described above.

Data were analyzed using SAS version 9.4 (SAS Institute, Cary, NC) and R[14] statistical programs, with $p < 0.05$ considered significant.

RESULTS

The study population consisted of 3,006,615 patients with EGS diseases who were treated at 4,083 hospitals across the USA in 2013.

Figure 1 shows the observed death rates in high- versus low-volume hospitals within each risk group of patients. It indicates that observed death rates started diverging when predicted mortality rates reached 4%. Patients with predicted death rates of 4% or higher experienced lower death rates at high-volume hospitals than at low-volume hospitals. This high-risk group contained 275,615 patients (9.2% of all EGS patients).

Table 1 summarizes multiple characteristics of the study population and compares low- versus high-risk patients. High-risk patients were older (78 ± 11 vs. 57 ± 19 years), less likely to be female (49% vs. 53%), more likely to be White (74% vs. 66%), and more likely to have Medicare insurance (82% vs. 44%). The mortality rate in high-risk patients was more than 10 times that in low-risk patients (8.1% vs. 0.8%, $p < 0.0001$). The rate of complications in high-risk patients was more than twice that in low-risk patients (51% vs. 23%, $p < 0.0001$). High-risk patients also experienced longer lengths of stay (median 5 vs. 3 days).

The mortality rate of high-risk patients treated at low-volume hospitals was significantly higher than for that of high-risk patients treated at high-volume hospitals (10.2%, 95% CI 9.9% to 10.5% vs. 7.7%, 95% CI 7.6% to 7.8%, $p < 0.0001$). Using these mortality rates, we estimate that 1,002 deaths could have been prevented if high-risk patients treated in low-volume hospitals had instead been transferred to high-volume hospitals. The mortality rate of low-risk patients was slightly higher at high-volume hospitals (0.51%, 95% CI 0.48% to 0.52% vs. 0.81%, 95% CI 0.80% to 0.82%, $p < 0.0001$).

Figure 2 depicts risk-adjusted death rates for each EGS disease category. It shows that risk-adjusted death rates exceeded 4% for 11 disease categories—shock, ruptured abdominal aneurysm, extremity thromboembolism, liver disease, perforation of intestine, esophagus disease, small intestinal cancer, bowel ischemia, colorectal cancer, non-traumatic bladder rupture, and peritonitis. Risk-adjusted death rates for individual ICD-9 diagnosis codes are provided in the supplemental table (see Table, Supplemental Digital Content 1, http://links.lww.com/TA/B177).

DISCUSSION

This study has 3 main findings. First, we observed a threshold of 4% predicted risk of death beyond which EGS patients appear to have lower mortality at high-volume hospitals than at low-volume hospitals. Second, over 90% of EGS patients had a low predicted risk of death, with no difference in outcome at low- versus high-volume hospitals. Hence, these patients may be treated safely at low-volume hospitals. Third, we have identified

11 specific EGS disease categories (shock, ruptured abdominal aneurysm, extremity thromboembolism, liver disease, perforation of intestine, esophagus disease, small intestinal cancer, bowel ischemia, colorectal cancer, non-traumatic bladder rupture, and peritonitis) for which mean predicted risk of death exceeds 4%; patients in these categories should be considered for transfer to high-volume hospitals.

Our findings are consistent with those of other studies that have reported better outcomes for patients with severe diseases who are treated at specialized centers. A study of hemorrhagic stroke found that patients admitted at comprehensive stroke centers had better survival than those admitted to other hospitals.[15] Studies of injured patients have shown that regionalized trauma systems led to an increase in the number of patients triaged to Level 1 trauma centers and significantly reduced hospital mortality for the critically injured patient population.[16,17] A study of cerebrovascular malformations found that treatment at high-volume institutions yielded superior outcomes and value, and the study advocated for triage of patients to high-volume institutions, which can serve as centers of excellence for cerebrovascular diseases.[18] For cancer, the volume–outcome relationship appears strong among high-risk, infrequently performed operations, such as those for esophageal cancer and pancreatic cancer,[19,20] as well as among more common cancers, such as breast and rectal. A study of breast cancer found that high-volume hospitals had significantly lower morbidity and mortality, shorter lengths of stay, and higher likelihoods of performing breast-conserving therapy.[21] Another study reported that rectal cancer patients who underwent surgery at high-volume hospitals were less likely to have permanent colostomy and had better survival rates than those treated at low-volume hospitals.[22] Our findings for EGS patients are consistent with these findings. Researchers have argued that hospital volume is often a measure of other hospital characteristics, such as surgeon experience or availability of a support team, and hence context of care is more important than hospital. Also, it is possible that differences exist in the processes of care at low- and high-volume hospitals.[20,22,23]

An important implication of our findings is the need to develop regionalized systems of care for EGS. Similar to trauma systems, EGS systems should be inclusive, with each hospital defining its scope of EGS practice based upon its capabilities and resources. This will enable hospitals to identify complex and critically ill patients whose clinical needs exceed local capabilities. Such patients should be considered for transfer to high-volume EGS centers that have the resources to care for high-risk patients. A regionalized system of EGS care, with transfer agreements between the hospitals, is needed to ensure consistent and efficient transfer of high-risk patients to high-volume hospitals. The findings of this study should reassure hospitals that only a small number of patients whose predicted risk of death exceeds 4% will need to be transferred out. These patients may be limited to those 11 high-risk EGS disease categories listed above. Over 90% of EGS patients are low risk and can be cared for at local hospitals. Hence, only a minority of EGS patients who are critically ill will require transfer to a high-volume center. Other approaches to improving the outcomes of high-risk EGS patients treated at low-volume hospitals could be explored. These may include telemedicine and periodic training of teams at low-volume hospitals for complex care.

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. It contains no data on anatomic severity of disease, physiologic status of the patient, whether diagnosis was present on admission or not, all of which may have a significant impact on patient outcomes. Also, we have no data on other outcomes, such as readmissions, costs, re-operations, or functional outcomes of survivors. Similarly, we have limited information on various characteristics of the hospitals. Specifically, we do not have any information on quality, quantity, or timeliness of care provided to these patients. Nor do we have any information on social determinants of health, such as family support, education level, personal habits, etc. However, our findings should spur further research into specific structures and processes of care at hospitals that can impact the outcomes of EGS patients. Also, each record in the NIS database represents one hospitalization. Hence, it is possible for an EGS patient with multiple hospitalizations to be counted multiple times, if the patient is transferred or readmitted after discharge. Another important limitation is that we analyzed all EGS diseases collectively, yet it is possible that certain EGS diseases are important predictors of the outcome. In developing this work, we considered disease-specific stratified analysis, but encountered poor statistical power because of the small number of outcome events for certain EGS diseases. Lastly, our estimate of patient risk is based upon discharge diagnosis, and not risk assessment at admission. A prospective study is needed to validate the findings of this study.

CONCLUSION

This study suggests that EGS patients with predicted risk of death of 4% or higher may benefit from transfer to high-volume EGS hospitals. Patients who should be included for transfer may include those presenting with shock, ruptured abdominal aneurysm, extremity thromboembolism, liver disease, perforation of intestine, esophagus disease, small intestinal cancer, bowel ischemia, colorectal cancer, non-traumatic bladder rupture, and peritonitis. The findings also underscore the need to develop regional systems of care for high-risk EGS patients.

DISCLOSURE

The authors have no conflicts of interest to declare.

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