# Quantifying lives lost due to variability in emergency general surgery outcomes: Why we need a national emergency general surgery quality improvement program

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**BACKGROUND:** Nearly 4 million Americans present to hospitals with conditions requiring emergency general surgery (EGS) annually, facing significant morbidity and mortality. Unlike elective surgery and trauma, there is no dedicated national quality improvement program to improve EGS outcomes. Our objective was to estimate the number of excess deaths that could potentially be averted through EGS quality improvement in the United States.

**METHODS:** Adults with the American Association for the Surgery of Trauma–defined EGS diagnoses were identified in the Nationwide Emergency Department Sample 2006 to 2014. Hierarchical logistic regression was performed to benchmark treating hospitals into reliability adjusted mortality quintiles. Weighted generalized linear modeling was used to calculate the relative risk of mortality at each hospital quintile, relative to best-performing quintile. We then calculated the number of excess deaths at each hospital quintile versus the best-performing quintile using techniques previously used to quantify potentially preventable trauma deaths.

**RESULTS:** Twenty-six million EGS patients were admitted, and 6.5 million (25%) underwent an operation. In-hospital mortality varied from 0.3% to 4.1% across the treating hospitals. Relative to the best-performing hospital quintile, an estimated 158,177 (153,509–162,736) excess EGS deaths occurred at lower-performing hospital quintiles. Overall, 47% of excess deaths occurred at the worst-performing hospitals, while 27% of all excess deaths occurred among the operative cohort.

**CONCLUSION:** Nearly 200,000 excess EGS deaths occur across the United States each decade. A national initiative to enable structures and processes of care associated with optimal EGS outcomes is urgently needed to achieve “Zero Preventable Deaths after Emergency General Surgery.” (*J Trauma Acute Care Surg.* 2021;90: 685–693. Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.)

**LEVEL OF EVIDENCE:** Care management, level IV.

**KEY WORDS:** Emergency general surgery; quality improvement; preventable deaths.

Emergency general surgery (EGS) encompasses a broad array of acute, resource-intensive surgical diseases and their management in some of the most critically ill patients.[1] While surgeons have been performing emergency surgery for centuries, the true burden of this disease entity has only recently been recognized.[1–3] Emergency general surgery conditions account for nearly 4 million incident cases and more than 2 million hospital admissions in the United States each year.[1] Patients with an EGS condition are at an increased risk of death (eight times more likely to die versus elective surgery), complications (one in two EGS patients develop a complication), and readmissions (15% are readmitted within 30 days).[3–6] In addition, the total annual cost of EGS care in the United States is an estimated US $28.4 billion, much higher than that for injury (US $19.4 billion), sepsis (US $17.1 billion), and myocardial infarction (US $11.0 billion).[7] However, despite having a high morbidity, mortality, and cost burden, there are currently no formal EGS data repository or quality improvement program.

The past few decades have seen substantial reductions in the morbidity and mortality for elective and trauma surgery patients. This was made possible, in large part, because of the establishment of disease-specific registries and data-centric performance improvement initiatives aimed at elevating quality of surgical care. Preeminent examples of these include the American College of Surgeons (ACS) National Surgical Quality Improvement Program and the Trauma Quality Improvement Program (TQIP), both of which use standardized data collection and analytics to undertake comparative hospital assessments and set performance benchmarks.[8,9] A central tenet of quality improvement is to mitigate hospital-level variation to reduce or eliminate adverse patient outcomes. Recent studies have suggested that, like elective and trauma surgery, EGS also suffers from hospital-level variation in quality of care, leading to calls for the establishment of an EGS quality improvement initiative.[10,11] However, little is known about the exact quantitative value and impact of such a performance improvement program.

One way to quantify the value and impact of an EGS quality improvement program is to determine the number of lives that could potentially be saved through improving the quality of care at low-performing hospitals. While determining a count of truly preventable deaths may require a case-by-case analysis of each mortality, an estimate of excess deaths attributable to variability in risk-adjusted mortality at lower-performing hospitals versus high-performing hospitals can be obtained. These excess deaths are calculated using the same observed-to-expected mortality ratios used to calculate risk-adjusted mortality and provide a complimentary measure of excess mortality burden. This method has previously been used to determine the estimate of excess deaths in civilian trauma.[12] For example, recent estimates suggest that improving trauma care at low-performing hospitals can potentially save up to 30,000 lives each year, leading to the National Academies of Sciences, Engineering and Medicine’s mandate to achieve “Zero Preventable Deaths after Injury.” Determining an estimate of these excess deaths EGS deaths will therefore be helpful in driving health care policy interventions to improve EGS outcomes. In addition, this will also provide a tangible target to evaluate future gains. Therefore, the objective of this study was to obtain a national estimate of the number of excess deaths that could potentially be averted if all patients received care at the highest performing hospitals for

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EGS in the United States. We hypothesize that substantial differences in hospital-level EGS quality of care exist, leading to a significant burden of excess EGS deaths.

## PATIENTS AND METHODS

We used data from the Agency for Healthcare Research and Quality Healthcare Cost and Utilization Project (HCUP) Nationwide Emergency Department Sample (NEDS) 2006 to 2014.[13] Nationwide Emergency Department Sample provides a 20% stratified sample of United States hospital-based emergency department (ED) visits from more than 900 hospitals across 30 states. Data in the NEDS are sampled from the State Inpatient Databases and the State Emergency Department Databases, which capture both inpatient admissions from the ED and ED visits that do not result in an admission, respectively. Nationwide Emergency Department Sample captures all ED encounters from the sampled hospitals, making it well suited for use in a hospital-level analysis. Poststratification weighting of NEDS allows for calculation of national estimates of ED visits and/or admissions from the ED, which makes this an ideal data set to undertake an epidemiological assessment of EGS outcomes.

Patient inclusions and exclusions are summarized in Figure 1. We used the American Association for the Surgery of Trauma–defined *International Classification of Disease, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnostic codes to identify adult patients (≥18 years old) who were admitted with a primary diagnosis of an EGS condition.[1] We used the recently proposed American Association for the Surgery of Trauma EGS definition because it is considered the criterion standard for describing the EGS population. The identified EGS cohort contained very little missing data with the highest proportion being for the variable death (0.07%) and insurance status (0.12%). Given the unequal distribution of missingness across individual hospitals, we excluded hospitals with a clustering of missing data (>20% missing) for death and insurance status. To ensure the reliability of benchmarking estimates, we additionally excluded hospitals reporting no deaths and those reporting <100 patients over the 9 years analyzed, which yielded the "All EGS" cohort.

Two subset cohorts of operative EGS were also developed. These were defined using primary *ICD-9-CM* procedure codes for 34 procedure groups among patients who underwent a major therapeutic procedure. These procedure groups were selected based on Scott et al.'s[14] previously published work defining operative EGS burden. This constituted the "Operative EGS" cohort. An additional cohort of seven high-burden EGS procedures (partial colectomy, small-bowel resection, cholecystectomy, operative management of peptic ulcer disease, lysis of peritoneal adhesions, appendectomy, and laparotomy) was also developed; this constituted the "High-Burden Operative EGS" cohort. This latter cohort was specifically included because these seven procedures have been shown to account for 80% of EGS admissions, deaths, complications, and inpatient costs and provide an actionable target for undertaking EGS quality improvement.[14]

Patient-level and hospital-level variables including age, sex, insurance status, patient zip code income quartile, length of stay, presence of major operative procedures, deaths, US census region, hospital teaching status, and urban-rural designation were extracted from the NEDS core files. Charlson Comorbidity

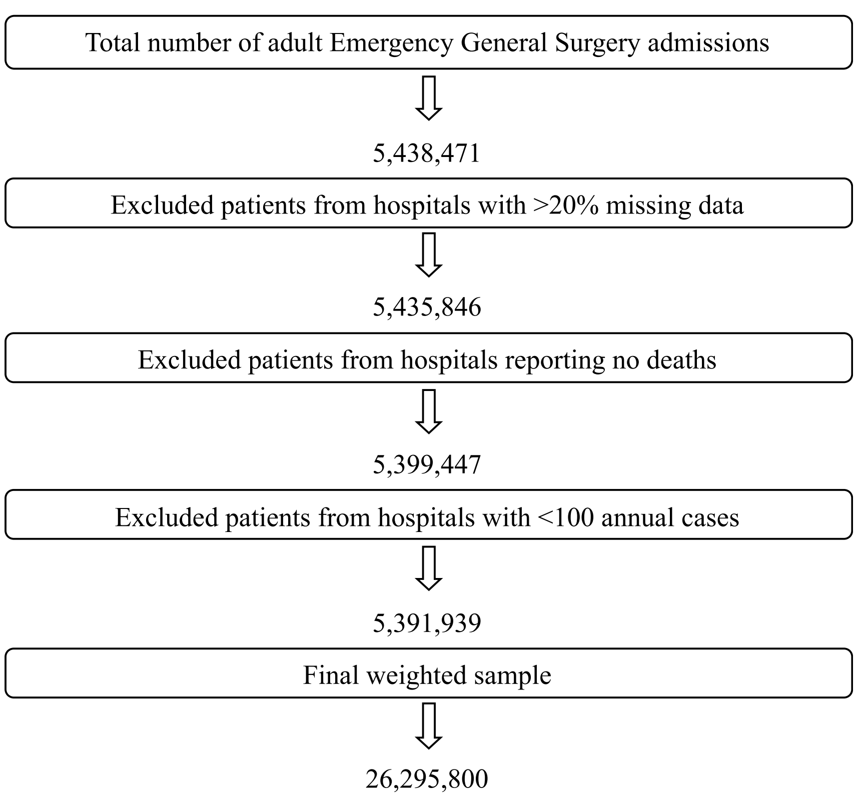


**Figure 1.** Patient selection from the unweighted HCUP NEDS 2006 to 2014.

 

**TABLE 1.** Patient Demographics and Clinical Characteristics Among EGS Patients

| | All EGS | | Operative EGS | | High-Burden Operative EGS | |
|---|---|---|---|---|---|---|
| | n = 26,295,800 | | n = 6,505,731 | | n = 5,182,775 | |
| | n | % | n | % | n | % |
| Age, y | | | | | | |
| 18–25 | 1,460,524 | 5.6 | 659,724 | 10.1 | 599,166 | 11.6 |
| 26–35 | 2,469,872 | 9.4 | 888,469 | 13.7 | 761,736 | 14.7 |
| 36–45 | 3,286,950 | 12.5 | 965,544 | 14.8 | 775,497 | 15.0 |
| 46–55 | 4,381,895 | 16.7 | 1,100,931 | 16.9 | 848,781 | 16.4 |
| 56–64 | 3,804,592 | 14.5 | 903,230 | 13.9 | 696,324 | 13.4 |
| 65–75 | 4,444,421 | 16.9 | 948,755 | 14.6 | 736,289 | 14.2 |
| 76–85 | 4,139,555 | 15.7 | 735,333 | 11.3 | 554,267 | 10.7 |
| >85 | 2,307,990 | 8.8 | 303,744 | 4.7 | 210,715 | 4.1 |
| Sex | | | | | | |
| Male | 12,211,744 | 46.4 | 2,930,515 | 45.0 | 2,227,056 | 43.0 |
| Female | 14,084,056 | 53.6 | 3,575,216 | 55.0 | 2,955,719 | 57.0 |
| Primary payer | | | | | | |
| Medicare | 12,056,643 | 45.9 | 2,129,641 | 32.7 | 1,576,799 | 30.4 |
| Medicaid | 3,313,293 | 12.6 | 849,002 | 13.1 | 667,474 | 12.9 |
| Private insurance | 7,484,589 | 28.5 | 2,518,925 | 38.7 | 2,150,112 | 41.5 |
| Self-pay | 2,289,864 | 8.7 | 680,883 | 10.5 | 534,260 | 10.3 |
| No charge | 290,157 | 1.1 | 87,327 | 1.3 | 68,327 | 1.3 |
| Other | 861,255 | 3.3 | 239,954 | 3.7 | 185,803 | 3.6 |
| Household income quartile for ZIP code | | | | | | |
| 0–25th | 7,245,695 | 27.6 | 1,674,964 | 25.7 | 1,281,060 | 24.7 |
| 26th–50th | 6,678,701 | 25.4 | 1,633,469 | 25.1 | 1,296,734 | 25.0 |
| 51st–75th | 6,190,413 | 23.5 | 1,583,851 | 24.3 | 1,282,617 | 24.7 |
| 76th–100th | 5,529,094 | 21.0 | 1,459,010 | 22.4 | 1,203,793 | 23.2 |
| missing | 651,898 | 2.5 | 154,438 | 2.4 | 118,571 | 2.3 |
| Charlson Comorbidity Index | | | | | | |
| 0 | 12,851,401 | 48.9 | 4,072,963 | 62.6 | 3,429,547 | 66.2 |
| 1 | 6,311,511 | 24.0 | 1,330,611 | 20.5 | 997,742 | 19.3 |
| 2 | 3,077,465 | 11.7 | 512,882 | 7.9 | 358,189 | 6.9 |
| ≥3 | 4,055,423 | 15.4 | 589,276 | 9.1 | 397,297 | 7.7 |
| Presence of any malignancy | 740,483 | 2.8 | 111,957 | 1.7 | 81,168 | 1.6 |
| Presence of metastatic solid tumor | 652,638 | 2.5 | 154,493 | 2.4 | 113,067 | 2.2 |
| Length of stay, d | | | | | | |
| 0 | 502,885 | 1.9 | 107,997 | 1.7 | 92,044 | 1.8 |
| 1–7 | 21,594,350 | 82.1 | 4,782,951 | 73.5 | 3,909,585 | 75.4 |
| 8–15 | 3,249,700 | 12.4 | 1,163,430 | 17.9 | 860,063 | 16.6 |
| 16–30 | 782,453 | 3.0 | 369,158 | 5.7 | 265,333 | 5.1 |
| >30 | 166,412 | 0.6 | 82,195 | 1.3 | 55,749 | 1.1 |
| Major operative procedure | 7,310,199 | 27.8 | N/A | N/A | N/A | N/A |
| Mortality | 404,955 | 1.5 | 107,345 | 1.7 | 81,370 | 1.6 |

N/A, not available.

Index was generated from *ICD-9-CM* diagnosis codes using the Charlson module for Stata.[15] The primary outcome of interest was in-hospital mortality.

We performed hierarchical logistic regression, with in-hospital mortality as the outcome, to benchmark individual hospitals in to quintiles of reliability-adjusted mortality rate using standardized techniques used for outcomes benchmarking elective and trauma surgical populations. An advantage of using reliability adjustment is that it accounts for low hospital volume–associated uncertainty in estimates by volume-dependent shrinkage of adjusted mortality rate to the overall average mortality rate.[16–18] This allows for more stable outcome estimate comparisons between hospitals of varying patient volume. Unlike trauma benchmarking, there is no standardized list of essential variables to benchmark EGS outcomes. Therefore, we included all clinically plausible variables in the model and performed a manual backward step-wise selection to arrive at the most parsimonious model with an equivalent *C* statistic. Multiple interaction terms were assessed, and collinearity was also tested using the variance inflation factor. The final overall model included age, sex, insurance status, Charlson

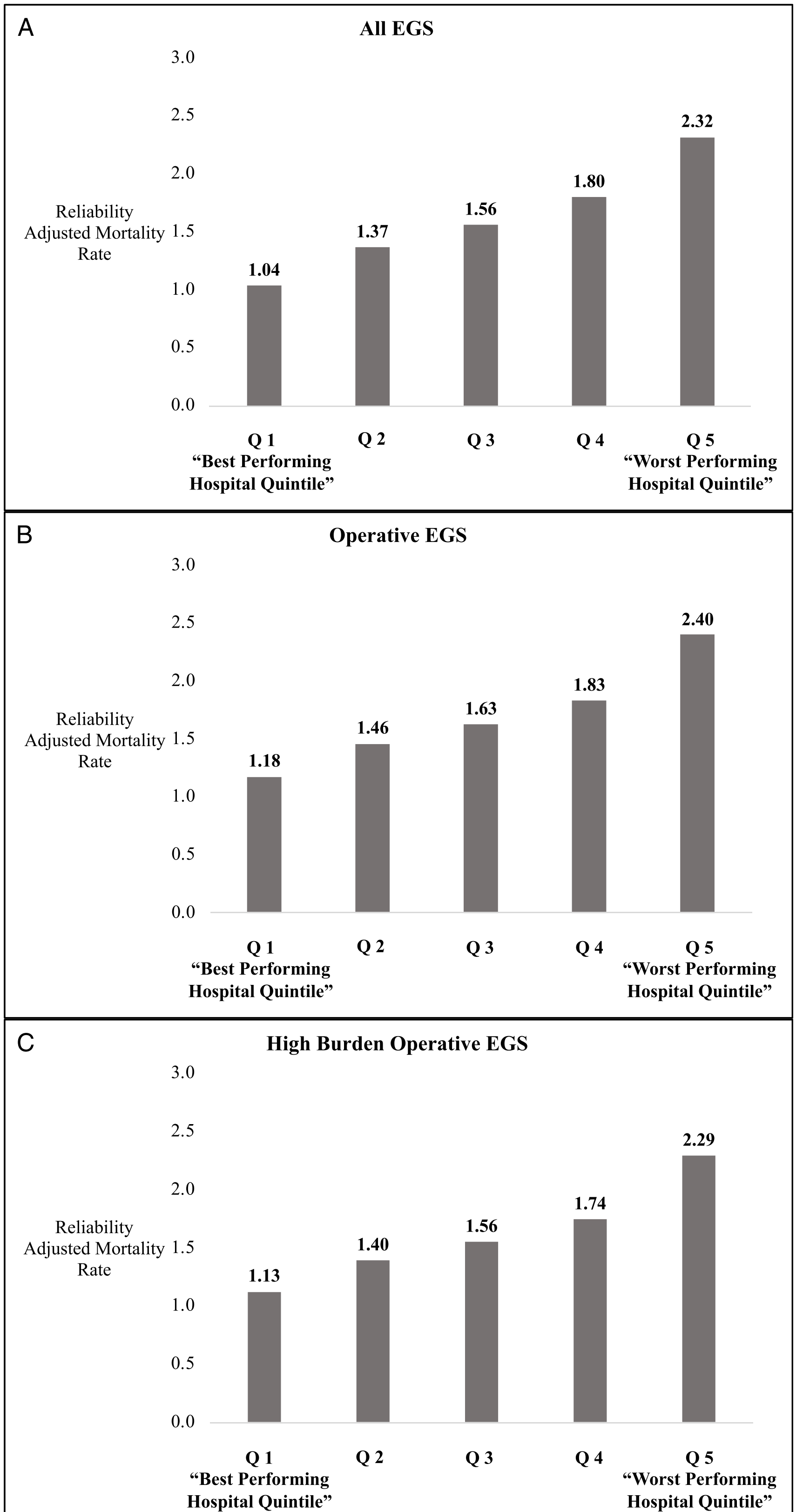


**Figure 2.** Hospital-level quintile variation in reliability-adjusted mortality rates for (*A*) All EGS, (*B*) Operative EGS, and (*C*) High-Burden Operative EGS cohorts.

**TABLE 2.** Difference in Demographics and Clinical Characteristics Between Patients Treated at Hospitals Among the Best- Versus the Worst-Performing Mortality Quintile

| | All EGS | | | Operative EGS | | | High-Burden Operative EGS | | |
|---|---|---|---|---|---|---|---|---|---|
| | Best-Performing Hospital Quintile (n = 5,859,716) | Worst-Performing Hospital Quintile (n = 5,623,863) | | Best-Performing Hospital Quintile (n = 1,756,448) | Worst-Performing Hospital Quintile (n = 1,273,948) | | Best-Performing Hospital Quintile (n = 1,461,981) | Worst-Performing Hospital Quintile (n = 1,055,190) | |
| | n (%) | n (%) | *p* | n (%) | n (%) | *p* | n (%) | n (%) | *p* |
| Age, y | | | | | | | | | |
| 18–25 | 351,097 (6.0) | 295,725 (5.3) | <0.01 | 184,343 (10.5) | 116,824 (9.2) | <0.01 | 178,130 (12.2) | 111,162 (10.5) | <0.01 |
| 26–35 | 597,540 (10.2) | 493,003 (8.8) | | 252,382 (14.4) | 159,853 (12.5) | | 231,418 (15.8) | 139,921 (13.3) | |
| 36–45 | 776,019 (13.2) | 681,408 (12.1) | | 269,219 (15.3) | 182,579 (14.3) | | 230,255 (15.7) | 150,159 (14.2) | |
| 46–55 | 1,001,970 (17.1) | 934,788 (16.6) | | 298,631 (17.0) | 218,011 (17.1) | | 241,126 (16.5) | 173,211 (16.4) | |
| 56–64 | 837,566 (14.3) | 833,128 (14.8) | | 238,017 (13.6) | 184,399 (14.5) | | 188,784 (12.9) | 150,079 (14.2) | |
| 65–75 | 944,958 (16.1) | 990,211 (17.6) | | 243,125 (13.8) | 197,902 (15.5) | | 192,927 (13.2) | 161,705 (15.3) | |
| 76–85 | 862,019 (14.7) | 907,213 (16.1) | | 190,154 (10.8) | 154,014 (12.1) | | 144,218 (9.9) | 123,943 (11.7) | |
| >85 | 488,548 (8.3) | 488,387 (8.7) | | 80,577 (4.6) | 60,365 (4.7) | | 55,123 (3.8) | 45,009 (4.3) | |
| Sex | | | | | | | | | |
| Male | 2,718,421 (46.4) | 2,629,213 (46.8) | 0.17 | 781,022 (44.5) | 578,750 (45.4) | <0.01 | 781,022 (44.5) | 578,750 (45.4) | <0.01 |
| Female | 3,141,294 (53.6) | 2,994,650 (53.2) | | 975,427 (55.5) | 695,197 (54.6) | | 234,429 (13.3) | 147,824 (11.6) | |
| Primary payer | | | | | | | | | |
| Medicare | 2,540,601 (43.4) | 2,678,149 (47.6) | <0.01 | 537,340 (30.6) | 454,445 (35.7) | <0.01 | 402,524 (27.5) | 354,701 (33.6) | <0.01 |
| Medicaid | 788,996 (13.5) | 657,347 (11.7) | | 234,429 (13.3) | 147,824 (11.6) | | 200,311 (13.7) | 116,644 (11.1) | |
| Private insurance | 1,711,771 (29.2) | 1,555,072 (27.7) | | 728,729 (41.5) | 471,218 (37.0) | | 636,290 (43.5) | 419,831 (39.8) | |
| Self-pay | 519,977 (8.9) | 506,697 (9.0) | | 162,000 (9.2) | 137,356 (10.8) | | 140,996 (9.6) | 112,435 (10.7) | |
| No charge | 95,020 (1.6) | 28,628 (0.5) | | 34,244 (1.9) | 14,048 (1.1) | | 27,579 (1.9) | 12,033 (1.1) | |
| Other | 203,351 (3.5) | 197,969 (3.5) | | 59,706 (3.4) | 49,056 (3.9) | | 54,281 (3.7) | 39,545 (3.7) | |
| Household income quartile for ZIP code | | | | | | | | | |
| 0–25th | 1,339,812 (23.5) | 1,944,736 (35.3) | <0.01 | 330,991 (19.3) | 424,932 (34.1) | <0.01 | 284,582 (20.0) | 336,792 (32.6) | <0.01 |
| 26th–50th | 1,358,962 (23.8) | 1,651,972 (30.0) | | 387,298 (22.6) | 364,535 (29.2) | | 317,737 (22.3) | 307,610 (29.8) | |
| 51st–75th | 1,559,938 (27.3) | 1,190,980 (21.6) | | 471,618 (27.5) | 286,584 (23.0) | | 374,077 (26.3) | 230,552 (22.3) | |
| 76th–100th | 1,454,521 (25.5) | 715,909 (13.0) | | 527,017 (30.7) | 171,188 (13.7) | | 446,372 (31.4) | 158,428 (15.3) | |
| Charlson Comorbidity Index | | | | | | | | | |
| 0 | 2,995,722 (51.1) | 2,643,965 (47.0) | <0.01 | 1,141,259 (65.0) | 754,780 (59.2) | <0.01 | 1,011,194 (69.2) | 661,021 (62.6) | <0.01 |
| 1 | 1,372,611 (23.4) | 1,383,721 (24.6) | | 343,305 (19.5) | 276,269 (21.7) | | 265,030 (18.1) | 216,723 (20.5) | |
| 2 | 641,531 (10.9) | 695,829 (12.4) | | 125,372 (7.1) | 114,171 (9.0) | | 88,861 (6.1) | 84,146 (8.0) | |
| ≥3 | 849,852 (14.5) | 900,348 (16.0) | | 146,513 (8.3) | 128,727 (10.1) | | 96,897 (6.6) | 93,300 (8.8) | |
| Presence of any malignancy | 158,098 (2.7) | 160,783 (2.9) | 0.02 | 29,215 (1.7) | 23,532 (1.8) | <0.01 | 21,187 (1.4) | 18,476 (1.8) | <0.01 |
| Presence of metastatic solid tumor | 135,225 (2.3) | 145,859 (2.6) | <0.01 | 39,061 (2.2) | 33,735 (2.6) | <0.01 | 27,826 (1.9) | 26,781 (2.5) | <0.01 |
| Length of Stay, d | | | | | | | | | |
| 0 | 140,164 (2.4) | 90,620 (1.6) | <0.01 | 33,159 (1.9) | 20,096 (1.6) | <0.01 | 27,533 (1.9) | 18,107 (1.7) | <0.01 |
| 1–7 | 4,924,627 (84.0) | 4,513,758 (80.3) | | 1,326,964 (75.5) | 894,217 (70.2) | | 1,141,519 (78.1) | 755,534 (71.6) | |
| 8–15 | 625,533 (10.7) | 776,004 (13.8) | | 287,892 (16.4) | 254,453 (20.0) | | 215,599 (14.7) | 200,888 (19.0) | |
| 16–30 | 142,132 (2.4) | 197,921 (3.5) | | 89,174 (5.1) | 84,983 (6.7) | | 64,414 (4.4) | 65,699 (6.2) | |
| >30 | 27,261 (0.5) | 45,560 (0.8) | | 19,260 (1.1) | 20,199 (1.6) | | 12,916 (0.9) | 14,961 (1.4) | |
| Major operative procedure | 1,629,407 (27.8) | 1,601,079 (28.5) | <0.01 | N/A | N/A | | N/A | N/A | |

N/A, not available.

Comorbidity Index, length of stay, presence of major operative procedure, and presence of cancer-related comorbidity. The operative EGS model was adjusted for age, sex, insurance status, Charlson Comorbidity Index, length of stay, presence of cancer-related comorbidity, and an interaction term between age and Charlson Comorbidity Index. The high-burden operative EGS cohort was adjusted for age, sex, insurance status, zip income quartile of median household income, Charlson Comorbidity Index, length of stay, and presence of cancer-related comorbidity. All models had *C* statistics of ≥0.86 and demonstrated adequate calibration as assessed using calibration curves. In addition, these models were similar to the models previously described by Ogola et al.[10] in their analysis of the EGS outcomes using administrative HCUP data.

Using the aforementioned models, hospitals were benchmarked into quintiles of reliability-adjusted mortality. National estimates of excess EGS deaths were calculated using the previously described method.[12,19] These were defined as greater-than-predicted number of deaths occurring at lower-performing hospital quintiles compared with the best-performing quintile. Briefly, we first calculated the number of observed deaths at each hospital quintile. Next, weighted generalized linear modeling with Poisson distributed deaths was performed to calculate the relative risk (RR) of mortality at each hospital quintile, relative to best-performing quintile. Finally, the number of excess deaths at each hospital quintile versus the best-performing quintile was calculated using the following equation:

$$\mathrm{ED} = O_i - [O_i \cdot \mathrm{RR}_i]$$

where ED denotes excess deaths, $O_i$ denotes number of observed deaths at quintile $I$, and $\mathrm{RR}_i$ denotes the RR of mortality at quintile $i$ relative to the best-performing quintile. A similar method has recently been used to describe national estimates of potentially preventable trauma mortality.[12]

All analyses were performed using Stata 14/MP statistical software package (StataCorp, College Station, TX). Level of significance was defined as $p < 0.05$ (two-sided) unless otherwise stated.

## RESULTS

The NEDS 2006 to 2014 contained approximately 5.4 million patients from 2,715 hospitals. After applying the inclusion/exclusion criteria described in the methods, a final sample of 5.3 million patients, weighted to 26.3 million discharges from 2,096 hospitals, was analyzed (Fig. 1). Table 1 describes the patient demographics and clinical characteristics among the three EGS cohorts. The Operative EGS and High-Burden Operative EGS cohorts identified 6.5 million patients at 1,641 hospitals (24.7% of All EGS) and 5.2 million patients at 1,547 hospitals (19.7% of All EGS), respectively. Patients among these latter cohorts were generally younger, privately insured or self-paying, with less comorbid burden and had a lower rate of malignant conditions versus the All EGS cohort. Mortality rates were similar between all three cohorts ranging from 1.5% for the All EGS patients to 1.7% among the Operative EGS cohort. For the All EGS cohort, in-hospital mortality varied from 0.3% to 4.1% across the treating hospitals. The most frequent nonoperative diagnoses included cellulitis, acute pancreatitis, and bowel obstruction (Supplemental Digital Content, Supplementary Table 1, http://links.lww.com/TA/B880).

Figure 2 describes the results of hospital mortality performance benchmarking across the three cohorts. Each subsequent hospital quintile had a significantly higher adjusted mortality rate. In addition, there was a greater than twofold difference between reliability-adjusted mortality rates for patients treated at hospitals among the best-performing versus the worst-performing quintile for all three cohorts. The highest mortality rate was observed among the worst quintile of hospitals treating Operative EGS patients (2.4%), whereas the lower rate was among the best-performing hospitals treating All EGS patients.

Table 2 describes the differences in demographics and clinical characteristics between patients treated at the best- versus the worst-performing hospitals. Because of the large sample size of the cohort, even subtle differences were found to be significant. However, several clinically important differences were also noted. For the All EGS cohort, a higher proportion of patients treated at the worst-performing hospitals were older than 65 years (42.4% vs. 39.1%, $p < 0.01$), had household income below the 50th percentile (65.3% vs. 47.3%, $p < 0.01$), had more comorbid disease burden (53% vs. 48.8% with Charlson Comorbidity Index ≥1, $p < 0.01$), and had a length of stay of >1 week (18.1% vs. 13.6%, $p < 0.01$). Similar trends were also noted among the two operative EGS cohorts.

Table 3 describes the national estimates of the number of excess EGS deaths. The RR of mortality was significantly

**TABLE 3.** National Estimates of Excess EGS Deaths

| Quintile of Reliability Adjusted Mortality Rate | All EGS: RR of Mortality* | All EGS: Number of Excess Deaths* | Operative EGS: RR of Mortality* | Operative EGS: No. Excess Deaths* | High-Burden Operative EGS: RR of Mortality* | High-Burden Operative EGS: No. Excess Deaths* |
|---|---|---|---|---|---|---|
| *Best-performing hospitals* | | | | | | |
| *Quintile 1* | 1 | Reference | 1 | Reference | 1 | Reference |
| Quintile 2 | 1.37 (1.33–1.40) | 16,981 (15,815–18,117) | 1.35 (1.29–1.41) | 3,866 (3,320–4,386) | 1.35 (1.28–1.43) | 2,706 (2,289–3,101) |
| Quintile 3 | 1.59 (1.55–1.63) | 25,254 (24,171–26,310) | 1.59 (1.51–1.66) | 6,257 (5,742–6,748) | 1.63 (1.55–1.71) | 4,793 (4,398–5,168) |
| Quintile 4 | 1.82 (1.78–1.86) | 41,481 (40,292–42,643) | 1.88 (1.80–1.97) | 10,984 (10,431–11,513) | 2.02 (1.93–2.12) | 8,901 (8,484–9,299) |
| *Worst-performing hospitals* | | | | | | |
| *Quintile 5* | 2.37 (2.32–2.42) | 74,462 (73,231–75,666) | 2.57 (2.47–2.68) | 21,471 (20,896–22,023) | 2.73 (2.58–2.89) | 18,060 (17,456–18,631) |
| Total no. excess EGS deaths (year 2006–2014) | N/A | 158,177 (153,509–162,736) | N/A | 42,577 (40,389–44,670) | N/A | 34,460 (32,627–36,199) |
| Annual no. excess EGS deaths | N/A | 17,575 (17,057–18,082) | N/A | 4,731 (4,488–4,963) | N/A | 3,829 (3,625–4,022) |

*Estimate with 95% confidence interval.
N/A, not available.

higher in each successive quintile of hospital performance compared with the best-performing quintile. The highest RR was observed among patients undergoing the high-burden operative EGS procedures (2.73 [2.58–2.89]) at the worst-performing hospital quintile. Relative to the best-performing hospital quintile, an estimated 158,177 (153,509–162,736) excess EGS deaths occurred at lower-performing hospital quintiles, that is, an estimated 17,575 (17,057–18,082) deaths per year. Nearly half of these deaths (n = 74,462; 47%) occurred at the worst-performing hospitals. An estimated 42,577 (40,389–44,670) excess EGS deaths occurred among patients undergoing an operative procedure. Overall, 27% of all excess EGS deaths occurred among the operative EGS cohort of which 81% (34,460) of deaths occurred in patients undergoing the seven high-burden EGS procedures. Complete results of the multivariable models are described in Supplemental Digital Content (Supplementary Tables 2 to 4, http://links.lww.com/TA/B880).

## DISCUSSION

This study, evaluating more than 26 million EGS admissions, establishes the potential value and impact of initiating an EGS quality improvement program in the United States. According to these estimates, nearly 200,000 excess EGS deaths occur across the United States each decade. Nearly half of these deaths occurred at the worst-performing quintile or the bottom 20% of the hospitals. Only 27% of these deaths occurred in patients who underwent any operative interventions, underscoring the need to study outcomes among those managed nonoperatively. In addition, seven high-burden EGS procedures accounted for more than 80% of the excess EGS deaths among those who underwent any operative procedure. These results suggest that a national initiative to enable structures and processes of care associated with optimal EGS outcomes is urgently needed to achieve "Zero Preventable Deaths after Emergency General Surgery."

The main results of this study, which suggest that approximately 18,000 EGS deaths occur each year in the United States, are in line with previously published accounts. Ogola et al.[10] recently performed an analysis of the HCUP Nationwide Inpatient Sample year 2010 and confirmed the existence of hospital-level variation in EGS mortality. As part of their secondary objectives, the authors determined that nearly 17,000 excess EGS deaths can potentially be prevented if all hospitals performed at the same level as the best-performing centers. Our current study builds on Ogola et al.'s[10] work and offers several improvements and additional insights. Firstly, we used a multiyear, nationally representative EGS cohort to calculate the burden of excess deaths. Aggregating and analyzing multiyear data result in higher case volume per hospital, yielding more precise outcome estimates, which is especially important given the lack of clinical granularity in this data set as discussed in the limitations section. In addition, because of recent changes in sampling design, multiyear hospital-level analysis can no longer be performed using the more recent Nationwide Inpatient Sample years.[13] Therefore, we chose to use NEDS to perform this analysis, which also allowed for the inclusion of more recent data. Second, we used multivariate hierarchical logistic regression to benchmark hospitals into performance quintiles based on reliability adjusted mortality rates. This technique is similar to methods already being used by the ACS National Surgical Quality Improvement Program and TQIP for hospital benchmarking and yields more stable outcome estimates especially when analyzing low-volume hospitals.[9,18] Lastly, we were also able to determine estimates of excess EGS deaths among patients who underwent an operative procedure.

While this study adds to a growing body of literature calling for the establishment of a dedicated EGS quality improvement program,[10] it also offers an insight as to which patients and hospitals need careful consideration when planning such an initiative. We found that a majority of excess deaths occurred in patients who were managed nonoperatively. This may be due to futility of operative intervention in high risk patients, delayed presentation resulting in severe physiologic derangements, diseases not amenable to operative interventions, or patient preference to defer surgery. Exact cause notwithstanding, the evaluation of nonoperative patient care should feature prominently in an EGS quality improvement program. In addition, in agreement with Scott et al.'s[14] work, we found that most of the excess deaths among the operative EGS patients can be adequately sourced by studying the seven high-risk EGS procedures. This could provide a manageable initial set of operative conditions to focus hospital performance benchmarking. Lastly, our finding that only a handful of hospitals account for almost 50% of the excess death burden suggests that targeted interventions at these lowest-performing centers may result in the best return on investment for an EGS quality improvement program.

We recognize and acknowledge a few important limitations of this study. Foremost, we acknowledge that not all deaths attributed to interhospital variation in quality of care may be preventable. Short of performing a case-by-case review, truly preventable deaths will be particularly challenging to define even with an EGS-specific quality improvement program. The initial aim of any EGS quality improvement program will likely be to make the participants aware of their performance estimates with the assumption that more in-depth analysis of deaths will be undertaken at individual hospitals similar to how the ACS TQIP currently functions for trauma benchmarking.[9]

The remainder of the limitations arises because of the use of an administrative database with its inherent shortcomings. First, NEDS does not contain any clinical information, such as laboratory or radiologic indices, to ascertain the severity or acuity of illness. Second, temporal and longitudinal assessment of individual patient outcomes is not possible. Therefore, we could not study relevant parameters such as timeliness of care, failure of initial nonoperative management, reoperations, and readmissions. Third, the NEDS also does not capture some of the social determinants of patient outcomes, such as goals-of-care discussions and changing treatment intents based on patient/family's beliefs and wishes. Therefore, strategies to mitigate these data limitations should be considered when designing an EGS-specific database. However, in the absence of such data, the NEDS remains the best nationally representative database to study EGS outcomes in the United States.

## CONCLUSIONS

Nearly 200,000 excess EGS deaths occur across the United States each decade. Therefore, a national initiative to programmatically study and deliver optimal EGS care is urgently needed to achieve "Zero Preventable Deaths after Emergency General Surgery."

## AUTHORSHIP

Z.G.H., M.P.J., J.M.H., J.W.S., E.G., Z.C., A.S., and A.H.H. conceived and designed the analysis. Z.G.H., M.P.J., J.M.H., and J.W.S. collected the data. E.G., Z.C., A.S., and A.H.H. contributed data or analysis tools. Z.G.H. and M.P.J. performed the analysis. Z.G.H. wrote the initial article. Z.G.H., M.P.J., J.M.H., J.W.S., E.G., Z.C., A.S., and A.H.H. performed critical review and revisions to the article.

## DISCLOSURE

The authors declare no conflicts of interest.

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