# A calculator for mortality following emergency general surgery based on the American College of Surgeons National Surgical Quality Improvement Program database

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Submitted: November 4, 2016, Revised: February 15, 2017, Accepted: March 13, 2017, Published online: March 21, 2017.
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Presented at the 102nd American College of Surgeons Clinical Congress, October 16th to 20th, 2016, in Washington, DC.
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DOI: 10.1097/TA.0000000000001451

**BACKGROUND:** The complex nature of current morbidity and mortality predictor models do not lend themselves to clinical application at the bedside of patients undergoing emergency general surgery (EGS). Our aim was to develop a simplified risk calculator for prediction of early postoperative mortality after EGS.

**METHODS:** EGS cases other than appendectomy and cholecystectomy were identified within the American College of Surgeons National Surgery Quality Improvement Program database from 2005 to 2014. Seventy-five percent of the cases were selected at random for model development, whereas 25% of the cases were used for model testing. Stepwise logistic regression was performed for creation of a 30-day mortality risk calculator. Model accuracy and reproducibility was investigated using the concordance index (c statistic) and Pearson correlations.

**RESULTS:** A total of 79,835 patients met inclusion criteria. Overall, 30-day mortality was 12.6%. A simplified risk model formula was derived from five readily available preoperative variables as follows: 0.034*age + 0.8*nonindependent status + 0.88*sepsis + 1.1 (if bun ≥ 29) or 0.57 (if bun ≥18 and < 29) + 1.16 (if albumin < 2.7), or 0.61 (if albumin ≥ 2.7 and < 3.4). The risk of 30-day mortality was stratified into deciles. The risk of 30-day mortality ranged from 2% for patients in the lowest risk level to 31% for patients in the highest risk level. The c statistic was 0.83 in both the derivation and testing samples.

**CONCLUSION:** Five readily available preoperative variables can be used to predict the 30-day mortality risk for patients undergoing EGS. Further studies are needed to validate this risk calculator and to determine its bedside applicability. (*J Trauma Acute Care Surg.* 2017;82: 1094–1099. Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.)

**LEVEL OF EVIDENCE:** Prognostic/epidemiological study, level III.

**KEY WORDS:** Emergency; mortality; risk; surgery.

Emergency general surgery (EGS) is an umbrella term that represents a heterogeneous collection of illnesses and patients connected only by their emergent nature. The diversity of EGS patients creates a clinical challenge due to the wide distribution of postoperative morbidity and mortality.[1] Although many models exist to help predict patient morbidity and mortality, recent studies demonstrate that the estimates provided by these elective models may not accurately reflect the risk for patients undergoing EGS.[2] Furthermore, many of these models require a large number of patient and operative variables which limits their application at the bedside of an EGS patient.

The volume of EGS patients in the United States is on the rise while access to such care continues to decline. Inherently, this has led to a shortage of medical resources with a lack of knowledge on how best to distribute them.[3] In a study published by Gale et al.[3] in 2014, the incidence of hospital admissions in 2010 for EGS was 1,290 admissions per 100,000 people, exceeding that of many common public health diseases, including coronary artery disease, all types of cancer, and new-onset diabetes mellitus.

Early mortality after EGS is estimated to be as high as 13% to 18%, a risk which is at least eight times higher than that associated with elective general surgery.[1,4,5] As the burden of EGS continues to grow, the need to accurately and efficiently risk stratify this heterogeneous patient population will be crucial to setting patient, family, and physician expectations. The purpose of our study was to develop a 30-day mortality risk calculator for patients undergoing EGS using the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database.

## MATERIALS AND METHODS

All patients undergoing EGS from the years 2005 through 2014 were identified within the NSQIP database by Current Procedural Terminology codes. Specifically, all patients who underwent EGS for perforated peptic ulcer disease, small- or large-bowel disease requiring bowel resection, incarcerated or strangulated umbilical, inguinal, femoral, or ventral hernia repair, and those patients who underwent debridement of necrotizing fasciitis were identified with the following Current Procedural Terminology codes: 43840, 44602, 49905, 44120, 44125, 44140, 44141, 44143, 44144, 44150, 44151, 44155, 44156, 44160, 49561, 49566, 49568, 49507, 49521, 49553, 49557, 49587, 11004, 11043, and 11046.

A procedure-specific calculator was not generated as we wanted to limit the complexity of the mortality risk model. Patients who underwent appendectomy and cholecystectomy were intentionally excluded from this analysis because these cases are often performed on an outpatient basis despite their urgent nature. Finally, encoded within the NSQIP database is an "emergency" variable which was required for case inclusion to ensure that nonemergent cases were excluded from our analysis.

Seventy-five percent of the cases identified within the NSQIP database were selected at random to be included in a derivation sample, whereas the remaining 25% of cases were used for model testing. To strengthen the accuracy of this model, only preoperative, objective variables were eligible for model inclusion. Laboratory values were coded into quartiles with "missing" being a fifth possible code.

Within the model derivation group, the association of preoperative patient demographics, comorbidities, and laboratory values with 30-day mortality was first investigated using univariate analysis. Student's *t* test was used for continuous variables, whereas $\chi^2$ or Fisher's exact test was used for categorical variables. Variables that had a significant association with 30-day mortality at a *p* value less than 0.10 in univariate analysis were then included in a multivariate model. Multivariate logistic regression was used to identify the variables that had an independent association with 30-day mortality while controlling for relevant covariates. A backward-elimination approach was used in which predictors with *p* value greater than 0.10 were dropped at each step to allow for a final model.

All variables that had a significant association with 30-day mortality after multivariate logistic regression were used to generate an initial mortality risk calculator. This risk calculator was then simplified by eliminating those variables that had a weaker association with 30-day mortality using the

concordance index (c statistic) as a measure of model strength. The concordance index is a reflection of the probability that, for each pair of randomly chosen patients, the patient with a higher risk score for mortality is the patient that is less likely to survive.[6] A value for the c-index greater than 0.8 indicates good discrimination.[7] This means that the patient with the higher risk of mortality is the one who is accurately predicted to die 80% of the time.[8] Variables were ranked based on the parameter estimate divided by the standard error, where a larger score indicates a more important predictor. Less important predictors were removed with the c statistic reexamined at each step. We kept variables in the final model that allowed the c statistic to drop by no more than 0.03 points while remaining greater than 0.8.

The simplified mortality risk model was used to calculate a risk score for each subject within both the model derivation and model testing groups using the same regression equation. Following the standard practice for assessing model testing, the mortality risk scores were stratified into deciles.[9] The calibration of the model was assessed in both the derivation and testing data sets by examining the predicted versus observed incidence of 30-day mortality in each decile using the coefficient of determination ($R^2$). In a perfectly calibrated model, the plot of predicted versus observed incidence of 30-day mortality across deciles should form a regression line with slope = 1.0 and y-intercept = 0. The reproducibility of the risk model was investigated by examining Pearson correlations between model parameters in the derivation and testing data sets. Model discrimination was examined using c statistics in both data sets.

SAS version 9.3 (Cary, NC) was used for all data analyses with $p$ values less than 0.05 considered significant.

## RESULTS

A total of 79,835 patients underwent EGS from the years 2005 through 2014; 59,716 of these cases were included in the derivation sample, whereas 20,119 of these cases were included in the testing sample. With respect to preoperative patient demographics, the average age of patients in the derivation group was 63.1 years, whereas the average of patients in the testing group was 63.3 years. Most patients in both groups were women (52.2% in the derivation group vs 52.6% in the validation group).

The association of preoperative patient variables with 30-day mortality in the derivation group is outlined in Table 1. All variables except sex were significantly associated with 30-day mortality. Although the definition of preoperative sepsis is available within the ACS-NSQIP Participant User File, we believe that it is important to define. For this study, preoperative sepsis was defined as any patient who met criteria for a systemic inflammatory response plus either a positive blood culture or infection site culture or preoperative presence of an infection as the indication for surgery, that is, systemic inflammatory response plus bowel strangulation.[10]

Next, the association of preoperative patient laboratory values with 30-day mortality was investigated in univariate analysis. As mentioned previously, to perform this analysis, patients were divided into quartiles, with quartile 1 corresponding to the lowest laboratory values and quartile 4 corresponding to the highest laboratory values present in the dataset. Patients with a higher white blood cell count ($p < 0.0001$), a lower hematocrit level ($p < 0.0001$), a lower platelet count ($p < 0.001$), a lower sodium level ($p < 0.001$), a higher blood urea nitrogen level (BUN; $p < 0.001$), a higher creatinine level ($p < 0.0001$), a lower serum

**TABLE 1.** Association of Preoperative Patient Variables With 30-Day Mortality, Derivation Group

| Variable | All Patients (N = 59,716) | Patients Dead at 30 d (N = 7,503) | Patients Alive at 30 d (N = 52,213) | *p* |
|---|---|---|---|---|
| Age (mean, SD), y | 63 ± 17 | 72 ± 13 | 62 ± 17 | <0.0001 |
| Female sex (N, %) | 31,155 (52%) | 3,983 (53%) | 27,172 (52%) | 0.15 |
| Body mass index (mean, SD), kg/m$^2$ | 29 ± 9 | 28 ± 10 | 29 ± 9 | <0.0001 |
| Nonindependent functional status (N, %) | 11,247 (19%) | 3,429 (31%) | 4,074 (8%) | <0.0001 |
| Current smoker (N, %) | 14,108 (24%) | 1,638 (22%) | 12,470 (24%) | <0.0001 |
| Hypertension (N, %) | 32,467 (54%) | 5,240 (70%) | 27,227 (52%) | <0.0001 |
| CHF (N, %) | 1,975 (3%) | 746 (10%) | 1,229 (2%) | <0.0001 |
| Dyspnea on exertion (N, %) | 7,639 (13%) | 2,125 (28%) | 5,514 (11%) | <0.0001 |
| COPD (N, %) | 6,316 (11%) | 1,627 (22%) | 4,689 (9%) | <0.0001 |
| Ascites (N, %) | 3,694 (6%) | 1,035 (14%) | 2,659 (5%) | <0.0001 |
| ESRD (N, %) | 2,254 (4%) | 799 (36%) | 1,455 (3%) | <0.0001 |
| Acute kidney injury (N, %) | 2,324 (4%) | 838 (11%) | 1,486 (3%) | <0.0001 |
| Chronic steroid use (N, %) | 5,335 (9%) | 1,244 (17%) | 4,091 (8%) | <0.0001 |
| Disseminated cancer (N, %) | 2,704 (5%) | 643 (9%) | 2,061 (4%) | <0.0001 |
| Weight loss > 10% (N, %) | 2,918 (5%) | 802 (11%) | 2,116 (4%) | <0.0001 |
| Bleeding disorder (N, %) | 8,079 (14%) | 1,929 (26%) | 6,150 (12%) | <0.0001 |
| Active wound infection (N, %) | 4,017 (7%) | 997 (13%) | 3,020 (6%) | <0.0001 |
| Preoperative sepsis (N, %) | 29,541 (50%) | 5,769 (77%) | 23,772 (50%) | <0.0001 |

N, number; AA, African American; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; ESRD, end-stage renal disease.

**TABLE 2.** 30-Day Mortality Risk Calculator

| Patient Factor | Patient Information |
|---|---|
| Age | _____ years |
| Nonindependent functional status* | ☐ Yes |
| | ☐ No |
| Preoperative sepsis** | ☐ Yes |
| | ☐ No |
| BUN | _____ mg/dL |
| Albumin | _____ g/dL |

Risk of 30-day mortality = 0.034*age + 0.8*nonindependent status + 0.88*sepsis + 1.1 (if BUN ≥ 29) or 0.57 (if BUN ≥ 18 and <29) + 1.16 (if albumin < 2.7) or 0.61 (if albumin ≥ 2.7 and <3.4).

BUN, blood urea nitrogen.

albumin level ($p < 0.001$), a higher bilirubin level ($p < 0.0001$), a higher alkaline phosphatase level ($p < 0.001$), a higher partial thromboplastin time (PTT; $p < 0.001$), and a higher international normalized ratio ($p < 0.0001$) were significantly more likely to experience 30-day mortality. The patient characteristics and laboratory tests that were found to be most strongly associated with 30-day mortality in multivariate logistic regression were age, nonindependent functional status, the presence of preoperative sepsis, blood urea nitrogen level, and serum albumin level. Based on the strength of association of these variables with 30-day patient mortality, a mortality risk equation was generated as follows (Table 2):

Risk of 30-day mortality = 0.034*age + 0.8*nonindependent status + 0.88*sepsis + 1.1 (if BUN ≥ 29) or 0.57 (if BUN ≥ 18 and <29) + 1.16 (if albumin < 2.7) or 0.61 (if albumin ≥ 2.7 and <3.4).

The discrimination of this model was good in both the derivation c statistic = 0.83 (95% confidence interval [CI], 0.82–0.83) and testing c statistic = 0.83 (95% CI, 0.82–0.84) data sets. In the validation data set, there was a strong linear association between predicted risk of 30-day mortality and actual incidence of 30-day mortality across risk deciles (Fig. 1A), with $R^2 = 0.99$. The regression line of predicted versus observed incidence had a slope of 0.97 and y-intercept of 0.004, indicating excellent model calibration. The same was true in the testing data (Fig. 1B), with $R^2 = 0.98$, slope = 0.96, and y-intercept = 0.005. The Pearson correlation between the model parameters in the derivation and testing data sets was $r = 0.97$, indicating good reproducibility of the risk calculator. As shown in Figure 2, the observed 30-day mortality in the testing group ranged from 2% (95% CI, 1%–2%) in the lowest decile to 31% (95% CI, 29%–33%) in the highest decile. A score ≤ 14.44 corresponded to decile one, >14.44–17.66 to decile two, >17.66–19.72 to decile three, >19.72–21.56 to decile four, >21.56–23.32 to decile five, >23.32–25.04 to decile six, >25.04–26.79 to decile seven, >26.79–28.55 to decile eight, >28.55–30.49 to decile nine, and >30.49 to decile ten. There was good discrimination between each risk decile with a narrow confidence interval for each decile, indicating high precision of the mortality risk calculator.

## DISCUSSION

Several models have been proposed to help predict morbidity and mortality for particular cohorts of surgical patients. For example, the American Society of Anesthesiologists developed the American Society of Anesthesiologists classification as a way to predict perioperative mortality for patients undergoing all types of surgery.[11–13] The Goldman Index and the Revised Cardiac Index have been proposed to help predict the risk of cardiac complications and cardiac mortality in patients undergoing noncardiac surgery.[14–16] The Acute Physiology and Chronic Health Evaluation (APACHE) II score was

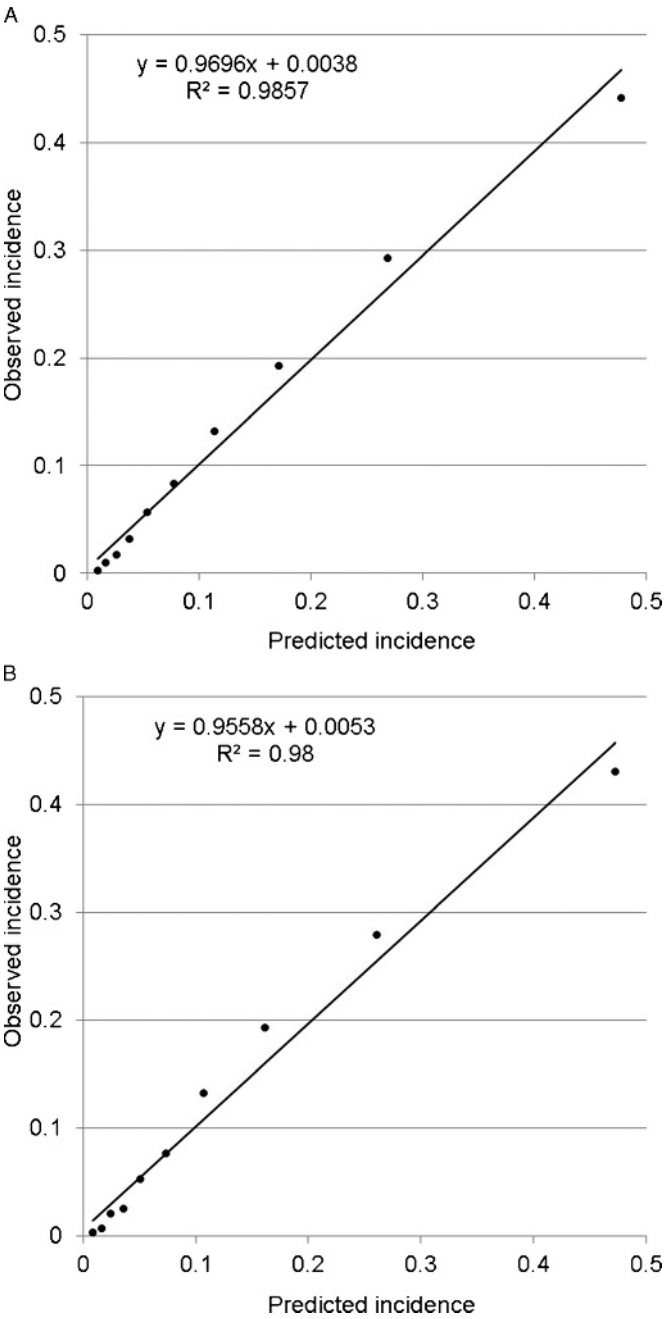


**Figure 1.** Calibration graph. With perfect calibration, the points should fall along a line with slope = 1 and y-intercept = 0. Each point represents the observed versus mean predicted probability of 30-day mortality within each risk score decile for (*A*) derivation sample and (*B*) testing sample.

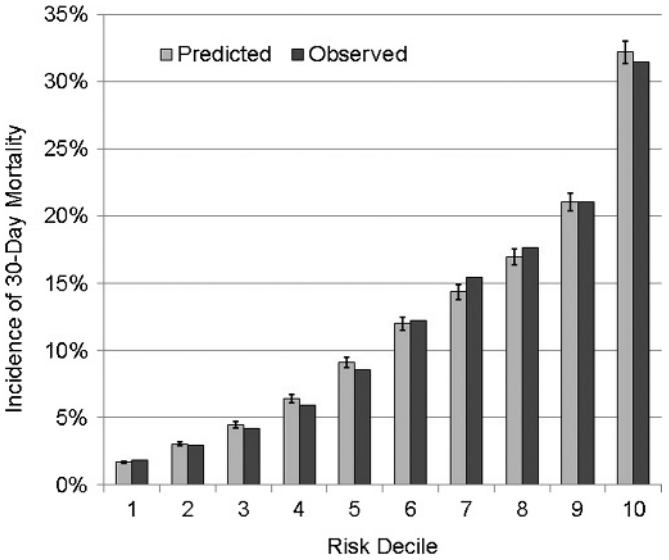


**Figure 2.** Predicted and observed incidence of 30-day mortality, stratified by risk decile, in the testing sample.

originally proposed for risk stratification of patients admitted to the intensive care unit but has since been adopted for the use in trauma surgery and other emergent general surgery cases.[17] Finally, an ACS-NSQIP surgical risk calculator was proposed in 2013 based on 21 patient variables found within the NSQIP database.[18] Although commonly used, all of these models have intrinsic limitations, either due to the use of subjective variables or the lack of generalizability to an EGS patient.[1,2,17,19–24]

The Affordable Care Act calls for transitioning from a volume-based physician reimbursement model to a quality-based model.[25] Within this new model, outcomes are measured based on the ratio of the quality of care delivered to the cost required to deliver such care (value = quality/cost).[26,27] Following suit to this rapidly evolving healthcare marketplace came the development of the ACS-NSQIP database. ACS-NSQIP is the first nationwide, validated, 30-day outcomes-centric database being used by academic, community, and academic-affiliated hospitals to measure quality of surgical care.[28] The ACS-NSQIP includes surgical outcomes from over 600 hospitals and is believed to be representative of surgical practices throughout the United States.[29]

The ACS-NSQIP published a universal surgical risk calculator in 2013.[18] This risk calculator uses 21 preoperative variables, both objective and subjective, to generate patient-specific estimates of 30-day perioperative morbidity and mortality.[18,30] Although it may seem peculiar that we used the ACS-NSQIP database to generate an EGS mortality risk calculator when there is already a universal ACS-NSQIP surgical risk calculator, a recent study by Bohnen et al.[2] demonstrates that perioperative morbidity and mortality for patients undergoing EGS may not be accurately predicted by the ACS-NSQIP surgical risk calculator. Furthermore, testing of the universal ACS-NSQIP surgical risk calculator during its derivation revealed that, when compared with procedure-specific ACS-NSQIP surgical risk calculators, the universal surgical risk calculator overestimates the risk of a morbidity and mortality event when an event is not observed and underestimates the risk of a morbidity and mortality event when an event is observed.[18] Furthermore, the ACS-NSQIP surgical risk calculator allows the surgeon to adjust the morbidity and mortality risk of a patient up to two standard deviations higher than that generated by the risk calculator.[18,30] Finally, there are no studies that have validated the universal ACS-NSQIP surgical risk calculator. These concerns for the applicability of the ACS-NSQIP surgical risk calculator, coupled with the additional variability introduced by the surgeon adjustment factor, exposes the need for patient- and/or procedure-specific risk calculators such as the one we propose for patients undergoing EGS.

Because of the inherent emergent nature of EGS procedures, preoperative optimization is limited or nonexistent. This strengthens the clinical utility of a risk calculator in this patient population as the values used in the equation will remain relatively unchanged. Furthermore, since our risk calculator uses five preoperative variables currently included in routine evaluation, calculation of a patient's mortality risk can be easily done quickly and efficiently at the bedside without delay of surgical intervention. It is our intention that the use of this risk calculator will help to appropriately counsel and establish goals of care for the EGS patient and successfully allocate limited medical resources. For example, if a patient has a high risk of postoperative mortality and this is presented to them during preoperative discussion, they may choose to forgo surgical intervention. On the contrary, if they choose to proceed with surgical intervention, the surgical team can prepare the operating room team and intensive care unit with the same risk calculator information so that all available resources can be used to help minimize the risk of postoperative mortality.

In our study, we attempted to create a risk stratification model for 30-day mortality specifically for patients undergoing EGS due to the aforementioned lack of applicability of current risk stratification models to this patient population.[1,20–23] We chose to use only objective preoperative variables to strengthen the clinical utility of our model. With this goal in mind, our 30-day mortality risk score for patients undergoing EGS is based on five preoperative variables including age, nonindependent functional status, the presence or absence of preoperative sepsis, preoperative BUN level, and preoperative serum albumin level. Age and nonindependent functional status are components of the initial patient history taken during the preoperative examination. The presence of sepsis, as well as BUN and albumin, are almost ubiquitous components of the preoperative evaluation, whether in an academic or a rural setting. Our risk calculator, therefore, uses five readily available preoperative variables without the need for additional patient work-up or laboratory results that would otherwise delay surgical intervention. In other words, the use of variables inherent to a preoperative examination enhances the accuracy of this risk calculator due to limited circumstances in which these variables would be missing.

We recognize that there are limitations to our study. First and foremost, the applicability of our 30-day mortality risk calculator relies on external validation and comparisons to currently available mortality risk calculators. The most commonly used risk calculator for patients undergoing EGS is the APACHE II score.[17] Several of the variables used to calculate the APACHE II score are not available within the ACS-NSQIP database. Currently, the authors are working on a follow-up

study comparing the clinical accuracy of this 30-day mortality risk calculator in a cohort of EGS patients from a single institution with the APACHE II score. Second, our risk calculator depends on multiplication of factors based on the presence or absence of preoperative variables. Although this may limit the ability to use this calculator at the bedside, the use of a spreadsheet or other electronic tool such as a phone application for input of patient values may circumvent this challenge. Third, our risk calculator is limited to short-term mortality outcomes. Further studies are needed to determine intermediate (i.e., 90 days postoperatively) and long-term mortality outcomes after EGS. Finally, some may argue that our risk calculator is not applicable to non–NSQIP-participating hospitals. However, the ACS-NSQIP has expanded significantly since its inception, from 121 participating hospitals in 2005 to now 603 participating hospitals that include a wide variety of hospital settings.[9]

## CONCLUSION

Patients undergoing EGS constitute a unique patient population with limited applicability of previously established perioperative risk calculators. Our study found that risk stratification of this heterogeneous patient population can be performed with five readily available preoperative patient variables with relative ease. The clinical accuracy of this risk calculator requires additional prospective studies.

### AUTHORSHIP

I.N.H., P.J.M., M.E.S., K.V., S.A., and B.S. conceived the study. I.N.H., R.L.A., and B.S. analyzed the data. I.N.H., P.J.M., M.E.S., R.L.A., K.V., and S.A. interpreted the data. I.N.H., P.J.M., and R.L.A. wrote the manuscript. I.N.H., M.E.S., R.L.A., K.V., S.A., and B.S. reviewed the final manuscript.

### DISCLOSURE

American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

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