Acute Care Surgery Model and Outcomes in Emergency General Surgery

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BACKGROUND: Annually, more than 2 million patients are admitted with emergency general surgery (EGS) conditions. Emergency general surgery cases comprise 11% of all general surgery operations, yet account for 47% of mortalities and 28% of complications. Using the statewide general surgery Michigan Surgical Quality Collaborative (MSQC) data, we previously confirmed that wide variations in EGS outcomes were unrelated to case volume/complexity. We assessed whether patient care model (PCM) affected EGS outcomes.

STUDY DESIGN: There were 34 hospitals that provided data for PCM, resources, surgeon practice patterns, and comprehensive MSQC patient data from January 1, 2008 to December 31, 2016 (general surgery cases = 126,494; EGS cases = 39,023). Risk and reliability adjusted outcomes were determined using hierarchical multivariable logistic regression analysis with multiple clinical covariates and PCM.

RESULTS: The general surgery service (GSS) model was more common (73%) than acute care surgery (ACS, 27%). Emergency general surgery 30-day mortality was 4.1% (intestinal resections 11.6%). The ACS model was associated with a reduction of 31% in mortality (odds ratio [OR] 0.69; 95% CI 0.52−0.92] for EGS cases, related to decreased mortality in the intestinal resection cohort (8.5% ACS vs 12% GSS, $p < 0.0001$). Morbidity in EGS was 17.4% (9.7% elective); highest (40%) in intestinal resection, and PCM did not affect morbidity. We identified specific variables for an optimal EGS risk adjustment model.

CONCLUSIONS: This is the first multi-institutional study to identify that an ACS model is associated with a significant 31% mortality reduction in EGS using prospectively collected, clinically obtained, research-quality collaborative data. We identified that new risk adjustment models are necessary for EGS outcomes evaluations. (J Am Coll Surg 2019;228:21−28. © 2018 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

General surgery is essential to health care delivery.[1] Emergency general surgery (EGS) is an important component of general surgery. Annually, more than 2 million patients are admitted with EGS conditions. Timely surgical assessment and operative management of EGS patients are required nationwide. Patients who require EGS procedures represent a distinct, high-risk population with frequent poor outcomes. Emergency general surgery cases comprise

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Abbreviations and Acronyms

ACS = acute care surgery
EGS = emergency general surgery
GSS = general surgery service
HIPAA = Health Insurance Portability and Accountability Act
IRB = institutional review board
MSQC = Michigan Surgical Quality Collaborative
OR = operating room
PCM = patient care model
PSO = patient safety organization
SCQR = surgical clinical quality reviewer

11% of all general surgery operations, yet account for 47% of mortalities and 28% of complications. Other single-institution studies have reported that acute care surgeon availability is associated with improved outcomes in EGS patient care, but this has not been validated across multiple centers.[2,3] Previous analysis of statewide Michigan Surgical Quality Collaborative (MSQC) data demonstrated that wide variations in EGS outcomes were unrelated to case volume/complexity.[4] To date, there are no studies linking institutional EGS process measures to prospectively collected data on patient outcomes across multiple different institutions. Within this context, we hypothesized that patient care model (PCM) would have significant impact on EGS patient outcomes.

METHODS

Patient population

The Michigan Surgical Quality Collaborative (MSQC) has a robust and well-established clinical registry and quality improvement (QI) infrastructure, with voluntary statewide participation by both academic and community hospitals. It is run by a project director and is overseen by an administrative center funded by Blue Cross Blue Shield of Michigan. At each participating MSQC hospital, a specially trained, dedicated surgical clinical quality reviewer (SCQR) abstracts and collects patient data and outcomes in accordance with established policies and procedures.[5-10] Thirty-four hospitals provided data for PCM, resources, surgeon practice patterns, and comprehensive MSQC patient data (January 1, 2008 to December 31, 2016) for general surgery cases (n = 126,494; EGS = 39,023).

All patients older than 18 years, who underwent intra-abdominal procedures exclusive of vascular or OB/GYN procedures, were included in our evaluation. Procedures were further sub-categorized into procedure groups based on Current Procedural Terminology (CPT) codes (eTables 1 and 2). The primary analysis was conducted on the entire cohort of patients and included surgical priority (urgent, emergent, and elective operations). Urgent cases were defined as an operation performed during index admission; emergent cases were defined as an operation performed for an emergency medical condition that is expected to result in a severe adverse patient outcome in the absence of surgery (typically performed within 24 hours of admission). Elective operations are scheduled in advance, with an outpatient interval between decision to operate and actual operation.

Outcomes measured

The primary outcomes for analysis were 30-day postoperative mortality and 30-day morbidity. Morbidity included surgical site infection, pulmonary complications, cardiovascular complications, infectious complications, venothromboembolic (VTE) disease, transfusion requirements, and renal dysfunction (eTable 3).

Covariates

Statewide hospital demographics and patient care models

We identified key hospital characteristics and care model factors not fully elucidated in the current MSQC database. These factors included hospital volume and demographics, surgeon team demographics, and patient care practice models currently in place for EGS care at each hospital. We obtained these key elements via outreach to the MSQC hospitals' Surgeon Champions for self-reported survey responses. Survey data were collected by site registrars (SCQR survey) and via interviews with practicing surgeons who care for EGS patients at each respective site. Of the hospitals in the Collaborative, a total of 34 sites responded to our surveys during the time frame of this study (September 2015 to March 2017). Patient care model was determined based on survey response. The acute care surgery (ACS) model was defined as sites with dedicated ACS surgeons covering care for EGS patients. The general surgery service (GSS) model was defined as sites where the elective general surgeons covered care for EGS patients. Four sites had a hybrid model, which had a combination of ACS and GSS surgeons caring for EGS patients. Overall patient outcomes data were then linked to survey results by the MSQC headquarter staff, and given back to the investigators for analysis in a deidentified fashion to protect hospital anonymity.

Statewide patient characteristics

Overall patient outcomes for EGS procedures were analyzed with the entire MSQC dataset (n = 308,243 cases). Outcome (mortality and morbidity) variability was assessed for all intra-abdominal EGS procedures;

vascular and OB/GYN cases were excluded (n = 215,742 cases meeting inclusion criteria). Model-specific outcomes data used only the limited dataset for the 34 sites that participated in our survey (n = 126,494 cases). Patient factors used in our analysis included baseline demographics (age, sex, race, smoking status), functional status, American Society of Anesthesiologists (ASA) physical status classification, and pre-existing medical conditions. Many of these covariates are the same as what is used for risk adjustment by the American College of Surgeons National Surgical Quality Improvement Program (NSQIP).[11]

Statistical analysis

Risk and reliability adjusted outcomes were determined using hierarchical multivariable logistic regression analysis, with multiple clinically relevant covariates and PCM. Categorical variables were tested using chi-square or Fisher's exact test if there were small cell sizes, to examine association with 30-day mortality or morbidity, respectively. Variables that were considered statistically or clinically significant from bivariate analysis were considered for inclusion in multivariable, hierarchical, logistic regression models for mortality and morbidity. Both stepwise logistic regressions and clinically relevant variables were considered to adjust for risk factors associated with each outcome. Each of the models was fit independently to evaluate multivariable associations after controlling for other clinically or statistically significant factors.

Variables with collinearity in candidate models were assessed by using Spearman or Pearson correlation matrices; therefore, final regression models excluded suspected collinear covariates. Final models for mortality and morbidity each were developed with clinical patient or case factors as fixed effects and hospital as the random effect to account for clustering of patients within hospitals. This is an approach of reliability adjustment that results in shrinkage of hospitals' adjusted mortality or morbidity rates toward the overall MSQC collaborative-wide rate, and further accounted for low hospital-specific case volumes.

Model fit was assessed via examination of quartile and decile analyses of the observed and predicted mortality or morbidity, the C-statistic as a measure of concordance, and careful examination of the Pearson chi-square residuals to identify any issues with over dispersion. For risk and reliability adjusted mortality or morbidity, hospital-specific 95% confidence intervals were calculated, and comparison to the MSQC collaborative-wide mortality or morbidity rate was used to identify high and low performing outlier hospitals. Hospitals whose 95% confidence interval of their risk and reliability adjusted mortality or morbidity rate that did not cross the collaborative-wide mean were considered statistical outliers. Final hierarchical logistic regression models were fit using PROC GLIMMIX with SAS Version 9.4 (SAS Institute). All significance tests were examined at the $\alpha = 0.05$ level.

Human subject consideration

This project was based entirely on existing data sources and the proposed analysis of secondary data. All protected health information was maintained in strict compliance with HIPAA and according to University policy. Additional institutional review board (IRB) approval was obtained; due to the deidentified nature of the MSQC database, this study was deemed exempt from IRB oversight. Work done within the MSQC is also protected under Patient Safety Organization (PSO) regulations.

RESULTS

Statewide hospital characteristics and care models

Hospital demographics

We received survey results from a total of 34 sites within the statewide collaborative. The distribution of hospital settings from medical centers that responded were: urban 14 of 34 (42%), rural 10 of 34 (30%), and suburban 9 of 34 (27%). They were mainly level 2 trauma centers (12 of 34; 36%). Community and private nonprofit hospitals comprised 14 of 34 (42%) and 10 of 34 (30%), respectively, of those who responded. A total of 25 of 34 (75%) were teaching hospitals; 20 of 34 (59%) had some type of a surgical residency program and 7 of 34 (21%) did not have any type of residency.

Hospital structure

The annual inpatient volume of the hospitals that responded to our survey was in the range of 10,000 to 30,000 patients/year, with 11 of 34 sites (33%) having volumes of less than 10,000 patients/year and 13 of 34 (40%) having between 10,000 and 30,000 patients/year. Only 7 of 34 sites (21%) had annual volumes greater than 1,000 EGS procedures; the majority of sites (11 of 34; 33%) performed fewer than 200 EGS operations per year. The total inpatient bed capacity varied widely between 100 and 500 beds, with 7 of 34 (21%) having less than 100 beds and 8 of 34 (24%) having more than 500 beds. Eight of 34 sites (24%) had fewer than 5 total operating rooms (ORs), 11 of 34 sites (32%) had 5 to 10 ORs, and 10 of 34 sites (29%) had 10 to 20 ORs. Nearly 50% of sites had OR dedicated block-time, OR support staff, and OR anesthesia available for EGS patients for all 7 days of the week. All the hospitals had x-ray technicians and respiratory therapists available 24/7 in-house. Other ancillary staff were available 24/7 in 50% to 80% of the hospitals: ultrasound

technicians (50%), CT technicians (80%), clinical lab technicians (94%), interventional radiology staff (24%), gastrointestinal capability (27%), and radiology interpretation staff (62%).

Emergency general surgery care team models

The majority of the hopitals (25 of 34; 74%) had a general surgery service (GSS) model compared with 5 of 34 (14%) with an acute care surgery (ACS) model and 4 of 34 (12%) with a hybrid model for EGS patient care. The hybrid model was defined as a combination of EGS patient care coverage by both ACS and GSS. Twenty-seven of 34 sites (79%) had a 24-hour surgeon call coverage structure for EGS patients; 32 of 34 (97%) had a different surgeon on call each night, and surgeons at 18 of 34 sites (58%) covered both EGS and trauma patients while on call. Only 20 of 34 sites (59%) had a backup call system. In 19 of 34 (59%), there were only 3 to 6 surgeons in the call pool. The reported average response time was less than 30 minutes in 17 of

Table 1. Morbidity Models for All Cases Stratified by Emergency vs Elective Procedures

Variable	All cases, Odds ratio (95% CI)	Emergency only, Odds ratio (95% CI)	Elective only, Odds ratio (95% CI)
Age category			
<65 y	Reference	Reference	Reference
65 to 75 y	1.26 (1.20−1.32)	1.33 (1.22−1.45)	1.21 (1.14−1.29)
75 to 85 y	1.38 (1.30−1.46)	1.46 (1.33−1.60)	1.32 (1.23−1.43)
≥85 y	1.52 (1.40−1.64)	1.53 (1.36−1.72)	1.43 (1.27−1.61)
ASA classification			
ASA class < 3	Reference	Reference	Reference
ASA class ≥3	2.31 (2.21−2.42)	2.68 (2.47−2.92)	2.04 (1.92−2.16)
Ascites			
Preoperative	1.68 (1.46−1.93)	1.55 (1.30−1.85)	1.60 (1.24−2.07)
Intraoperative	1.38 (1.05−1.81)	1.18 (0.86−1.60)	1.55 (0.81−2.95)
Cancer	1.46 (1.34−1.60)	1.46 (1.25−1.72)	1.50 (1.35−1.67)
Congestive heart failure	NA	1.43 (1.19−1.73)	2.05 (1.62−2.58)
Chronic condition	1.62 (1.50−1.75)	1.51 (1.34−1.71)	1.60 (1.44−1.78)
Dependent functional status	2.13 (1.93−2.36)	1.94 (1.73−2.19)	2.16 (1.76−2.65)
Diabetes	1.12 (1.07−1.18)	1.11 (1.02−1.20)	1.10 (1.03−1.17)
Dialysis	NA	1.30 (1.08−1.55)	1.40 (1.14−1.71)
Sex	NA	NA	1.11 (1.06−1.17)
Hypertension	1.22 (1.17−1.27)	1.22 (1.13−1.31)	1.20 (1.13−1.27)
History of peripheral vascular disease		1.36 (1.17−1.59)	1.35 (1.17−1.56)
Model of care			
General surgery service	Reference	Reference	Reference
Acute care service	NS	NS	NS
Hybrid model	NS	NS	NS
Surgical approach			
Open	Reference	Reference	Reference
Laparoscopic	0.24 (0.23−0.25)	0.22 (0.21−0.24)	0.27 (0.25−0.29)
Surgical priority			
Elective	Reference	NA	Reference
Urgent/emergent	1.32 (1.26−1.38)	Reference	NA
Ventilator dependent	3.14 (2.72−3.63)	2.99 (2.52−3.55)	2.70 (1.96−3.71)
Wound classification			
Clean	Reference	Reference	Reference
Clean-contaminated	3.49 (3.30−3.69)	2.04 (1.81−2.30)	NA
Contaminated	3.79 (3.54−4.07)	2.19 (1.93−2.48)	NA
Dirty-infected	5.52 (5.14−5.92)	3.33 (2.96−3.75)	NA

ASA, American Society of Anesthesiologists; NA, not applicable; OR, odds ratio.

Table 2. Mortality Models for All Cases Stratified by Emergency vs Elective Operations

Variable	All cases, Odds ratio (95% CI)	Emergency only, Odds ratio (95% CI)	Elective only, Odds ratio (95% CI)
Age category			
<65 y	Reference	Reference	Reference
65 to 75 y	2.13 (1.87–2.42)	2.02 (1.71–2.39)	2.21 (1.78–2.74)
75 to 85 y	3.49 (3.08–3.97)	3.24 (2.75–3.82)	3.76 (3.03–4.67)
≥85 y	5.61 (4.84–6.51)	4.70 (3.88–5.69)	6.99 (5.42–9.02)
ASA classification			
ASA class < 3	Reference	Reference	Reference
ASA class ≥3	6.75 (5.54–8.21)	8.73 (6.36–11.98)	4.30 (3.31–5.59)
Ascites			
Preoperative	3.50 (2.90–4.22)	2.92 (2.34–3.65)	4.99 (3.49–7.12)
Intraoperative	2.52 (1.72–3.69)	1.98 (1.29–3.02)	7.34 (3.07–17.57)
BMI, kg/m^2 category			
18.5 to 25	Reference	Reference	Reference
<18.5	1.28 (1.08–1.53)	1.30 (1.04–1.61)	1.34 (0.98–1.82)
25 to 30	0.74 (0.65–0.83)	0.74 (0.64–0.87)	0.71 (0.58–0.85)
30 to 35	0.81 (0.71–0.93)	NS	0.75 (0.60–0.94)
35 to 40	0.63 (0.52–0.76)	0.67 (0.52–0.86)	0.57 (0.41–0.80)
≥ 40	0.70 (0.57–0.86)	0.72 (0.55–0.93)	NS
Cancer	2.63 (2.25–3.07)	2.58 (2.08–3.19)	2.64 (2.09–3.32)
Congestive heart failure	2.60 (2.16–3.14)	2.51 (2.01–3.13)	2.93 (2.07–4.16)
Chronic condition	1.76 (1.52–2.04)	1.9 (1.59–2.26)	1.35 (1.01–1.81)
Dialysis	2.35 (1.93–2.86)	2.25 (1.77–2.85)	2.53 (1.74–3.68)
Dependent status	1.79 (1.54–2.09)	1.93 (1.64–2.28)	
Sex	NA	0.82 (0.73–0.93)	0.71 (0.61–0.83)
History of peripheral vascular disease	1.72 (1.44–2.06)	1.58 (1.27–1.98)	1.85 (1.36–2.50)
Hypertension	NA	NA	1.33 (1.10–1.59)
Model of care			
General surgery service	Reference	Reference	Reference
Acute care surgery	0.71 (0.54–0.92)	0.69 (0.52–0.92)	NS
Hybrid	NS	NS	NS
Race (white)	NA	1.24 (1.04–1.49)	NA
Surgical approach			
Open	Reference	Reference	Reference
Laparoscopic	0.26 (0.22–0.30)	0.18 (0.15–0.23)	0.38 (0.31–0.46)
Surgical priority			
Elective	Reference	NA	Reference
Emergency	2.06 (1.86–2.29)	Reference	NA
Ventilator dependent	6.46 (5.47–7.63)	5.85 (4.85–7.06)	7.23 (4.87–10.73)
Wound classification			
Clean	Reference	Reference	Reference
Clean-contaminated	3.18 (2.67–3.80)	2.04 (1.57–2.64)	4.74 (3.67–6.12)
Contaminated	4.37 (3.58–5.32)	2.79 (2.13–3.67)	6.88 (5.07–9.34)
Dirty-infected	6.09 (5.04–7.36)	3.80 (2.94–4.91)	9.98 (7.28–13.69)

ASA, American Society of Anesthesiologists; NA, not applicable; OR, odds ratio.

34 (63%) of the hospitals. In more than 50% of the hospitals, the on call surgeon covered the night and weekend decision making and the follow-up care for EGS patients. The model of elective general surgeons covering elective surgery at same time as EGS was seen in 13 of 34 (40%) of the hospitals. Nearly 80% of surgeons believed

Table 3. Mortality Outcomes for Emergency General Surgery vs Elective Patient Cases Stratified by Patient Care Model

General surgery procedure mortality, 30-d	All cases (n = 126,494)	Emergency general surgery (n = 39,023)	Elective (n = 87,471)
All patients, n (%)	2,358 (1.9)	1,584 (4.1)	774 (0.9)
Acute care surgery model			
Adjusted odds ratio	0.71	0.69	0.73
95% CI	0.54–0.92	0.52–0.92	0.52–1.02
p Value	<0.001	0.001	0.063
n	21,559	7,177	14,382
General surgery model, n, referent	81,715	31,846	56,287

that they have uniform practices in the care of EGS patients. The EGS surgeon mostly had other concurrent responsibilities such as teaching/administrative in 17 of 34 (50%), research in 8 of 34 (24%), and clinical in 22 of 34 (65%) sites.

Statewide patient outcomes analyses

There were a total of 308,243 patient cases in the MSQC registry between January 1, 2008 and December 31, 2016. Outcome (mortality and morbidity) variability was assessed for all EGS procedures, with a focus on intra-abdominal procedure categories (n = 215,742 cases). Model-specific outcomes data used only the limited dataset for the 34 sites that participated in our care models survey (n = 126,494 cases). A sensitivity analysis was conducted comparing the responding hospitals vs all hospitals in the collaborative. The patient population proportions were very similar, and the responding hospital subset was deemed to be a fair representation of the overall collaborative.

In our study population, the EGS 30-day mortality was 4.1% overall (11.6% in intestinal resections). Factors for patient mortality and morbidity were modeled after NSQIP covariates, as previously published.[11] After risk/reliability adjustment, hospital model type was significant for mortaliy (Table 1), but not statistically significant for morbidity (Table 2). After risk adjustment, the ACS model was associated with a 31% mortality reduction (odds ratio 0.69; 95% CI 0.52 to 0.92) for EGS cases, related to decreased mortality in the intestinal resection cohort (8.5% ACS vs 12% GSS, $p < 0.0001$). Morbidity from EGS was 17.4% (9.65% elective); the highest (40%) was in intestinal resections (Tables 3 and 4).

DISCUSSION

Since its introduction in the early 2000s, many centers have moved toward establishing an acute care surgery model for the care of emergency general surgery patients.[1-3,12-15] Individual centers have reported improved select EGS patient outcomes after development of an ACS service compared with historical cohorts[16-18] or between a small number of affiliated institutions.[19] To our knowledge, this is the first study to evaluate the correlation between patient care model and contemporaneous EGS patient outcomes across multiple institutions using a prospectively collected patient outcomes data registry.

We evaluated EGS patient outcomes overall as well as stratified by the most common operative categories. Our results are consistent with those from previous studies in that EGS patients have greater mortality and morbidity when compared to their elective operative counterparts.[20] A study comparing emergency with nonemergency colorectal resections, using the NSQIP data from 2005 to 2007, documented significantly higher rates of mortality (15.3% vs 1.9%) and complications (48% vs 23.9%) in EGS patients.[21] In this study, hospitals with favorable outcomes for nonemergency colorectal resections did not have the same outcomes for emergency operations.

Furthermore, different models of care exist for the management of EGS patients, yet there are limited data on how these differences affect patient outcomes. A recent study using a retrospective state administrative database found an association between ACS model and worse outcomes in patients with either appendicitis or cholecystitis.[22] In our study, further stratification by patient care model did not demonstrate any statistical difference in PCM contribution to EGS patient morbidity.

In our 30-day mortality analysis, there was a clear association between decreased mortality and the ACS model. The difference in mortality was most prominent in the subcategory of EGS patients undergoing intestinal resections, with a 30-day mortality rate of 11.6%, compared with the overall EGS mortality rate of 4.1% in our study. It is not surprising that this particular cohort of patients presents the highest rate for mortality and morbidity compared with the other subgroups.

We ran multiple risk adjustment models for EGS patient mortality and morbidity. Most risk adjustments to date have used the NSQIP model, which has been useful in predicting patient outcomes for most elective procedures. In

Table 4. Intestinal Resection Cohort Mortality Stratified by Patient Care Model

	All patients (n = 10,431)		Acute care surgery model (n = 1,984)		General surgery model (n = 8,447)	
Intestinal resection cohort mortality, 30-d	**n**	**%**	**n**	**%**	**n**	**%**
Death	1,190	11.6	165	8.5	1,025	12.1
Any complication	4,145	39.7	772	38.9	3,373	39.9

our study, we identified specific variables for an optimal EGS risk adjustment model, and found that the relative weight adjustments for risk is different for EGS patients when compared with the NSQIP model.[11] There were also differences in certain covariates, which would require further investigation over time to excluding sampling bias. As both the MSQC and NSQIP data collection processes continue to evolve for EGS patients, we anticipate that future studies will be able to delineate a more detailed model specific to EGS patients.

Strengths

There are many strengths to our study. The MSQC is a statewide data registry that has been prospectively collecting patient demographics and outcomes for more than a decade. It has been vetted across diverse hospital care settings, and boasts a robust reputation for inter-rater reliability in extracting meaningful outcomes data from a patient's medical records. Thirty-four hospital sites within the MSQC responded to our detailed surveys regarding hospital demographics as well as EGS surgeon practice models and characteristics. There was respresentation from both community and academic institutions, with a wide range across hospital size and trauma-center designation. We directly surveyed EGS surgeons at each site to ascertain details about their respective patient care models and processes. Likewise, we were able to obtain detailed information regarding hospital characteristics and resources through our survey responses. Our study is unique in that we were able to then correlate these hospital and PCM data back to the MSQC patient registry; the MSQC headquarters functioned as an intermediary to link the 2 databases, while at the same time maintaining hospital and patient deidentification. This resulted in the abilty to perform robust analyses on a large cohort of patients across multiple institutions.

Limitations

Our study has several limitations. Within our patient care models, there remains a degree of variability in how the specifc EGS patient care services are delivered. Due to the diverse nature of participating sites, a greater number of hospitals would need to be surveyed in order to provide adequate statistical association of mortality benefits with specific aspects of the PCMs. Survey responses were necesarily batched as part of the deidentification process, therefore negating some levels of granularity in our data. Furthermore, there were potential changes in EGS patient care patterns over time that may not have been fully captured in the survey. For example, the MSQC data collection and sampling methodology changed twice during the timeframe of our patient dataset; however, these changes happened uniformly across the entire state collaborative. In version 2.0 of the MSQC dataset, surgical priority was further stratified into urgent vs emergent; for the consistency of the dataset, we combined urgent and emergent priority into a single category.

Implications for future studies

This study is but the tip of the proverbial iceberg for EGS patient care. Further studies are needed to delve more deeply into specific PCM characteristics and the effect on EGS patient outcomes. Likewise, further patient demographics and surgical priority classification would help us better distinguish the contributions of predetermined patient comorbidities vs potentially modifiable institutional care patterns to allow for process improvement. Furthermore, a risk-stratification model tailored specifically to EGS patient care would better inform patients and family members of individualized risks, as well as institutional quality metrics.

CONCLUSIONS

Emergency general surgery patients are a distinct cohort, and best practice measures need to reflect that distinction. To our knowledge, this is the first multi-institutional study to identify that an ACS model is associated with a significant 31% mortality reduction in EGS using prospectively collected, clinically obtained, research-quality collaborative data. We identified that new risk adjustment models are necessary for EGS outcomes evaluations. This study demonstrates a unique opportunity for future EGS data collection to specifically target risk adjustment.

Author Contributions

Study conception and design: To, Napolitano, Patil, Seese, Englesbe

Acquisition of data: To, Napolitano, Patil, Seese, Collins, Krapohl, Englesbe, Campbell, Hemmila

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eTable 1. Procedure Type for Elective vs Emergency Status

	Elective (n = 87,471)		Emergency (n = 39,023)	
Procedure type	**n**	**%**	**n**	**%**
Appendectomy	3,859	4.41	14,092	36.11
Cholecystectomy	22,506	25.73	10,151	26.01
Colectomy	13,608	15.56	5,501	14.10
Proctectomy	1,300	1.49	76	0.19
Gastrectomy	693	0.79	256	0.66
Hepatectomy	870	0.99	30	0.08
Hernia repair	30,397	34.75	2,680	6.87
Pancreatectomy	1,472	1.68	119	0.30
Anti-reflux surgery	4,256	4.87	150	0.38
Small bowel procedure	3,068	3.51	3,951	0.12
Splenectomy	472	0.54	174	0.45
Other gastric procedure	818	0.94	864	2.21
Other colon procedure	4,152	4.75	979	2.51
Gastric procedure	1,511	1.73	1,120	2.87
All intestinal procedures	20,828	23.81	10,431	26.73
All abdominal procedures (excluding hernia)	57,074	65.25	36,343	93.13
All abdominal procedures	87,471	0.00	39,023	0.00

eTable 2. Common Procedural Terminology Codes Used in Analyses of Patient Outcomes

Procedure	Common procedural terminology code
Appendectomy	
Open	
Appendectomy	44950
Appendectomy; for ruptured appendix with abscess or general peritonitis	44960
Laparoscopic	
Laparoscopy, surgical, appendectomy	44970
Unlisted laparoscopy procedure, appendix	44979
Cholecystectomy	
Open	
Cholecystectomy	47600
Cholecystectomy; with cholangiography	47605
Cholecystectomy with exploration of common duct	47610
Cholecystectomy with exploration of common duct; with choledochoenterostomy	47612
Cholecystectomy with exploration of common duct; with transduodenal sphincterotomy or sphincteroplasty, with or without cholangiography	47620
Laparoscopic	
Laparoscopy, surgical; cholecystectomy	47562
Laparoscopy, surgical; cholecystectomy with cholangiography	47563
Laparoscopy, surgical; cholecystectomy with exploration of common duct	47564
Colectomy	
Open	
Colectomy, partial; with anastomosis	44140
Colectomy, with skin level cecostomy or colostomy	44141
Colectomy, with end colostomy and closure of distal segment	44143
Colectomy, with resection, with colostomy or ileostomy and creation of mucofistula	44144
Colectomy, with coloproctostomy (low pelvic anastomosis)	44145
Colectomy, with coloproctostomy (low pelvic anastomosis), with colostomy	44146
Colectomy with abdominal and transanal approach	44147
Colectomy, total, abdominal, without proctectomy; with ileostomy or ileoproctostomy	44150
Colectomy, total, abdominal, without proctectomy; with continent ileostomy	44151
Colectomy, total, abdominal, with proctectomy; with ileostomy	44155
Colectomy, total, abdominal, with proctectomy; with continent ileostomy	44156
Colectomy, total, abdominal, with proctectomy; with ileoanal anastomosis, includes loop ileostomy, and rectal mucosectomy, when performed	44157
Colectomy, total, abdominal, with proctectomy; with ileoanal anastomosis, creation of ileal reservoir (S or J), includes loop ileostomy, and rectal mucosectomy, when performed	44158
Colectomy, partial, with removal of terminal ileum with ileocolostomy	44160
Laparoscopic	
Laparoscopy, surgical; colectomy, partial, with anastomosis	44204
Laparoscopy, surgical; colectomy, partial, with removal of terminal ileum with ileocolostomy	44205
Laparoscopy, surgical; colectomy, partial, with end colostomy and closure of distal segment (Hartmann type procedure)	44206
Laparoscopy, surgical; colectomy, partial, with anastomosis, with coloproctostomy (low pelvic anastomosis)	44207
Laparoscopy, surgical; colectomy, partial, with (low pelvic anastomosis) with colostomy	44208
Laparoscopy, surgical; colectomy, total, abdominal, without proctectomy, with ileostomy or ileoproctostomy	44210
Laparoscopy, surgical; colectomy, total, abdominal, with proctectomy, with ileoanal anastomosis, creation of ileal reservoir (S or J), with loop ileostomy, includes rectal mucosectomy, when performed	44211
Laparoscopy, surgical; colectomy, total, abdominal, with proctectomy, with ileostomy	44212

(Continued)

eTable 2. Continued

Procedure	Common procedural terminology code
Proctectomy	
Open	
Proctectomy; complete, combined abdominoperineal, with colostomy	45110
Proctectomy; partial resection of rectum, transabdominal approach	45111
Proctectomy, combined abdominoperineal, pull-through procedure	45112
Proctectomy, partial, with rectal mucoscectomy, ileoanal anastomosis, creation of ileal reservoir (S or J), with or without loop ileostomy	45113
Proctectomy, partial, with anastomosis; abdominal and trans-sacral approach	45114
Proctectomy, partial, with anastomosis; trans-sacral approach only	45116
Proctectomy, combined abdominoperineal pull-through procedure, with creation of colonic reservoir, with diverting enterostomy when performed	45119
Proctectomy, complete (for congenital megacolon), abdominal and perineal approach; with pull-through procedure and anastomosis	45120
Proctectomy, complete (for congenital megacolon), abdominal and perineal approach; with subtotal or total colectomy, with multiple biopsies	45121
Pelvic exenteration for colorectal malignancy, with proctectomy (with or without colostomy), with removal of bladder and ureteral transplantations, and/orhysterectomy, or cervicectomy, with or without removal of tube(s), with or without removal of ovary(s), or any combination thereof	45123
Excision of rectal procidentia, with anastomosis; perineal approach	45130
Excision of rectal procidentia, with anastomosis; abdominal and perineal approach	45135
Excision of rectal tumor by proctotomy, trans-sacral or transcoccygeal approach	45160
Excision of rectal tumor, transanal approach; not including muscularis propria	45171
Excision of rectal tumor, transanal approach; including muscularis propria	45172
Laparoscopic	
Laparoscopy, surgical; proctectomy, complete, combined abdominoperineal, with colostomy	45395
Laparoscopy, surgical; proctectomy, combined abdominoperineal pull-through procedure, with creation of colonic reservoir, with diverting enterostomy, when performed	45397
Laparoscopy, surgical; proctopexy (for prolapse)	45400
Laparoscopy, surgical; proctopexy (for prolapse) with sigmoid resection	45402
Proctopexy; abdominal approach	45540
Proctopexy; with sigmoid resection, abdominal approach	45550
Anti-reflux surgery	
Open	
Esophagogastroduodenoscopy, flexible, transoral; diagnostic, including collection of specimen(s) by brushing or washing, when performed (separate procedure)	43210
Esophagogastric fundoplasty, with fundic patch (Thal-Nissen procedure)	43325
Esophagogastric fundoplasty partial or complete; laparotomy	43327
Esophagogastric fundoplasty partial or complete; thoracotomy	43328
Esophagomyotomy (Heller type); abdominal approach	43330
Esophagomyotomy (Heller type); thoracic approach	43331
Repair, paraesophageal hiatal hernia (including fundoplication), via laparotomy, except neonatal; without implantation of mesh or other prosthesis	43332
Repair, paraesophageal hiatal hernia (including fundoplication), via laparotomy, except neonatal; with implantation of mesh or other prosthesis	43333
Repair, paraesophageal hiatal hernia (including fundoplication), via thoracotomy, except neonatal; without implantation of mesh or other prosthesis	43334
Repair, paraesophageal hiatal hernia (including fundoplication), via thoracotomy, except neonatal; with implantation of mesh or other prosthesis	43335
Repair, paraesophageal hiatal hernia (including fundoplication), via thoracoabdominal incision, except neonatal; without implantation of mesh or other prosthesis	43336

(Continued)

eTable 2. Continued

Procedure	Common procedural terminology code
Repair, paraesophageal hiatal hernia (including fundoplication), via thoracoabdominal incision, except neonatal; with implantation of mesh or other prosthesis	43337
Unlisted procedure, esophagus	43499
Laparoscopic	
Laparoscopy, surgical, esophagomyotomy (Heller type), fundoplasty, when performed	43279
Laparoscopy, surgical, esophagogastric fundoplasty (eg Nissen, Toupet procedures)	43280
Laparoscopy, surgical repair of paraesophageal hernia, includes fundoplasty, when performed; without implantation of mesh	43281
Laparoscopy, surgical repair of paraesophageal hernia, includes fundoplasty, when performed; with implantation of mesh	43282
Small bowel procedure	
Open	
Enterolysis (freeing of intestinal adhesion) (separate procedure)	44005
Enterotomy, small intestine, other than duodenum; for exploration, biopsy(s), or foreign body removal	44020
Enterotomy, small intestine, other than duodenum; for decompression (eg Baker tube)	44021
Reduction of volvulus, intussusception, internal hernia, by laparotomy	44050
Correction of malrotation by lysis of duodenal bands and/or reduction of midgut volvulus (eg Ladd procedure)	44055
Enterectomy, resection of small intestine; single resection and anastomosis	44120
Enterectomy, resection of small intestine; with enterostomy	44125
Enteroenterostomy, anastomosis of intestine, with or without cutaneous enterostomy (separate procedure)	44130
Intestinal stricturoplasty (enterotomy and enterorrhaphy) with or without dilation, for intestinal obstruction	44615
Laparoscopic	
Laparoscopy, surgical, enterolysis (freeing of intestinal adhesion) (separate procedure)	44180
Laparoscopy, surgical, enterectomy, resection of small intestine, single resection and anastomosis	44202
Other esophageal procedures	
Open	
Diverticulectomy of hypopharynx or esophagus, with or without myotomy; cervical approach	43130
Diverticulectomy of hypopharynx or esophagus, with or without myotomy; thoracic approach	43135
Gastrointestinal reconstruction for previous esophagectomy, for obstructing esophageal lesion or fistula, or for previous esophageal exclusion; with stomach, with or without pyoroplasty	43360
Gastrointestinal reconstruction for previous esophagectomy, for obstructing esophageal lesion or fistula, or for previous esophageal exclusion; with colon interposition or small intestine reconstruction, including intestine mobilization, preparation, and anastomosis(es)	43361
Other colon procedures	
Open	
Placement, enterostomy or cecostomy, tube open (eg for feeding or decompression) (separate procedure)	44300
Placement, enterostomy or cecostomy, ileostomy or jejunostomy, non-tube	44310
Revision of ileostomy; simple (release of superficial scar) (separate procedure)	44312
Revision of ileostomy; complicated (reconstruction in-depth) (separate procedure)	44314
Colostomy or skin level cecostomy	44320
Colostomy or skin level cecostomy; with multiple biopsies (eg for congenital megacolon) (separate procedure)	44322
Revision of colostomy; simple (release of superficial scar) (separate procedure)	44340

(Continued)

eTable 2. Continued

Procedure	Common procedural terminology code
Revision of colostomy; complicated (reconstruction)	44345
Revision of colostomy; with repair of paracolostomy hernia (separate procedure)	44346
Suture of large intestine (enterorrhaphy) for perforated ulcer, diverticulum, wound, injury or rupture; single perforation	44602
Suture of large intestine (enterorrhaphy) for perforated ulcer, diverticulum, wound, injury or rupture; multiple perforations	44603
Suture of large intestine (colorrhaphy) for perforated ulcer, diverticulum, wound, injury or rupture (single or multiple perforation); without colostomy	44604
Suture of large intestine (colorrhaphy) for perforated ulcer, diverticulum, wound, injury or rupture (single or multiple perforation); with colostomy	44605
Closure of intestinal cutaneous fistula	44640
Closure of enteroenteric or enterocolic fistula	44650
Closure of enterovesical fistula; without intestinal or bladder resection	44660
Closure of enterovesical fistula; with intestine and/or bladder resection	44661
Excision of Meckel's diverticulum (diverticulectomy) or omphalomesenteric duct	44800
Excision of ileoanal reservoir with ileostomy	45136
Laparoscopic	
Laparoscopy, surgical; ileostomy or jejunostomy, non-tube	44187
Laparoscopy, surgical, colostomy or skin level cecostomy	44188
Laparoscopy, surgical, closure of enterostomy, large or small intestine, with resection and anastomosis	44227
Gastrectomy	
Open	
Gastrotomy, with exploration of foreign body removal	43500
Gastrectomy, total; with Roux-en-Y reconstruction	43621
Gastrectomy, partial, distal, with gastrojejunostomy	43632
Gastrectomy, partial, distal, with Roux-en-Y reconstruction	43633
Gastorrhaphy, suture of perforated duodenal or gastric ulcer, wound, or injury	43840
Hepatectomy	
Open	
Hepatectomy, resection of liver; partial lobectomy	47120
Hepatectomy, resection of liver; trisegmentectomy	47122
Hepatectomy, resection of liver; total left lobectomy	47125
Hepatectomy, resection of liver; total right lobectomy	47130
Hernia repair	
Open	
Repair initial incisional or ventral hernia; incarcerated or strangulated	49561
Repair initial incisional or ventral hernia; reducible	49560
Repair recurrent incisional or ventral hernia; incarcerated or strangulated	49566
Repair recurrent incisional or ventral hernia; reducible	49565
Reduction of volvulus, intussusception, internal hernia, by laparotomy	44050
Repair initial inguinal hernia, age 5 years or older; incarcerated or strangulated	49507
Repair recurrent inguinal hernia, any age; incarcerated or strangulated	49521
Repair, paraesophageal hiatal hernia (including fundoplication), via thoracotomy, except neonatal; without implantation of mesh or other prosthesis	43334

(Continued)

eTable 2. Continued

Procedure	Common procedural terminology code
Repair, paraesophageal hiatal hernia (including fundoplication), via laparotomy, except neonatal; without implantation of mesh or other prosthesis	43332
Laparoscopic	
Laparoscopy, surgical repair, incisional hernias (includes mesh insertion, when performed); incarcerated or strangulated	49655
Laparoscopy, surgical repair, incisional hernias (includes mesh insertion, when performed); reducible	49654
Laparoscopy, surgical, repair, recurrent incisional hernia (includes mesh insertion when performed); incarcerated or strangulated	49657
Laparoscopy, surgical, repair, recurrent incisional hernia (includes mesh insertion when performed); reducible	49656
Laparoscopy, surgical, repair, ventral umbilical, spigelian or epigastric hernia (includes mesh insertion when performed); incarcerated or strangulated	49653
Laparoscopy, surgical, repair, ventral umbilical, spigelian or epigastric hernia (includes mesh insertion when performed); reducible	49652
Splenectomy	
Open	
Splenectomy; total (separate procedure)	38100
Splenectomy; total en bloc for extensive disease, in conjunction with other procedure	38102
Laparoscopic	
Laparoscopy, surgical, splenectomy	38120
Pancreatectomy	
Open	
Excision of lesion of pancreas (eg cyst, adenoma)	48120
Pancreatectomy, distal subtotal, with or without splenectomy: without pancreatojejunostomy	48140
Pancreatectomy, proximal subtotal with total duodenectomy, partial gastrectomy, (Whipple-type procedure); with pancreatojejunostomy	48150
Pancreatectomy, proximal subtotal with total duodenectomy, partial gastrectomy, (Whipple-type procedure); without pancreatojejunostomy	48152
Pancreatectomy, proximal subtotal with near-total duodenectomy, choledochoenterostomy and duodenojejunostomy (pylorus-sparing, Whipple-type procedure); with pancreatojejunostomy	48153
Pancreatectomy, total	48155

eTable 3. Patient Demographics for Elective vs Emergency Procedures

	Elective (n = 87,471)		Emergency (n = 39,023)	
Demographic	**n**	**%**	**n**	**%**
Age				
<65 y	60,471	69.13	27,635	70.82
65–75 y	15,356	17.56	5,417	13.88
75–85 y	9,117	10.42	4,024	10.31
≥85 y	2,527	2.89	1,947	4.99
Female sex	40,448	46.24	17,717	45.40
Race (white)	69,699	85.14	29,924	81.62
BMI, kg/m^2 (median)				
Underweight (<18.5)	2,328	2.66	2,123	5.44
Normal weight (18.5–24.9)	20,045	22.92	10,398	26.65
Overweight (25–29.9)	27,165	31.06	11,550	29.60
Obese				
I (30–34.9)	18,500	21.15	7,443	19.07
II (35–39.9)	10,130	11.58	4,016	10.29
III (>40)	9,303	10.64	3,493	8.95
ASA classification				
Class 1	5,898	6.74	4,391	11.25
Class 2	44,102	50.42	16,955	43.45
Class 3	34,454	39.39	13,139	33.67
Class 4	2,922	3.34	4,193	10.74
Class 5	95	0.11	345	0.88
Wound classification				
Clean	32,958	37.68	3,239	8.30
Contaminated	54,513	62.42	35,784	91.71
Ascites	412	0.47	925	2.37
Presence of sepsis	65	0.07	5,475	14.03
Ventilator dependence	202	0.23	791	2.03
Dependent functional status	574	0.66	1,648	4.24
Disseminated cancer	2,310	2.64	824	2.11
Hypertension	39,951	45.67	15,820	40.54
Peripheral vascular disease	1,456	1.66	939	2.41
Congestive heart failure	407	0.47	615	1.58
Current smoker	20,731	23.70	10,639	27.26
COPD	2,950	7.68	2,148	7.96
Dialysis dependent	676	0.77	676	1.73

ASA, American Society of Anesthesiologists.