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RESEARCH ARTICLE

Time-to-operation and hospital mortality in emergency general surgery: Evidence from 6.8 million admissions supporting dedicated emergency general surgery services

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Abstract

Background: Delays of time-to-operation (TTO) in emergency general surgery (EGS) are common, but large-scale evidence on the impact of this delay on hospital mortality remains limited.
Objective: To evaluate the association between TTO and in-hospital mortality in EGS on both adult (18–64 years) and elderly (≥65 years) patients.
Methods: This retrospective study analyzed 6,805,380 EGS admissions from the National Inpatient Sample (2005–2014). Primary diagnoses were defined according to the American Association for the Surgery of Trauma (AAST) EGS classification. The primary exposure was TTO, defined as the number of days between hospital admission and the first operative intervention. The primary outcome was in-hospital mortality. Multivariable logistic regression models were adjusted for demographic characteristics, comorbidities, and frailty using a modified 5-item frailty index.
Results: A total of 6,805,380 patients were analyzed. Overall mortality was 1.7% (elderly: 4.2% vs. adults: 0.7%). Each day of delay increased mortality odds by 13.5% in adults with no comorbidities (odds ratio [OR] 1.135, 95% confidence interval [CI]: 1.12–1.15) and 9.3% in the elderly with no comorbidities (OR: 1.093, 95% CI: 1.08–1.11). Frailty amplified the risk of mortality (OR: 1.2–1.5, while surgery served as a protective factor (OR: 0.5–0.7 vs. non-operative management).
Conclusion: TTO is a modifiable mortality predictor in EGS in both adults and elderly patients. These results further support the recent initiative by the American College of Surgeons/AAST to establish dedicated EGS services, which reduces delays in TTO. Future prospective studies are needed to validate these findings.

Keywords: Emergency general surgery; Time-to-operation; Mortality; Frailty; National Inpatient Sample

1. Introduction

Emergency general surgery (EGS) accounts for 7–10% of United States' hospital admissions and 50% of surgical deaths, costing >$28 billion annually.[1-5] While the "golden hour" is well-established in trauma, the impact of time-to-operation (TTO) in EGS is understudied, particularly for high-risk subgroups like the elderly.[5-7] Evidence on EGS outcomes fails to account for the heterogeneous nature of EGS populations, and in particular, TTO.[8-12] Timely surgical intervention is crucial for optimal patient outcomes; however, significant delays in EGS are common worldwide. These delays stem from factors such as workforce shortages, inefficient operating room management, and patient-related barriers. Staffing deficiencies can prolong decision-making, while competition for limited operating room slots further delays EGS, particularly when conflicts arise with elective surgeries. Optimizing resource allocation and streamlining preoperative workflows are essential for improving EGS efficiency and patient outcomes.[12] A recent initiative by the American College of Surgeons (ACS) and the American Association for the Surgery of Trauma (AAST) to further enhance EGS outcomes involves the establishment of dedicated EGS services, aiming to provide focused resources and expertise in care delivery.[5,13] To examine the relationship between TTO and hospital mortality, we analyzed data from the National Inpatient Sample (NIS) spanning 2005 to 2014, focusing on AAST diagnoses of EGS admissions. We hypothesize that a longer TTO is associated with increased mortality, and there are differing mortality risks associated with delays in treatment between adult and elderly patients.

2. Methods

2.1. Study design and data source

This retrospective study analyzed data from the NIS database, which is part of the Healthcare Cost and Utilization Project, the largest collection of longitudinal hospital care data in the United States, between 2005 and 2014.[14] The NIS captures approximately seven million hospital discharges annually, excluding rehabilitation and long-term acute care facilities. This weighted sample allows for national estimates of hospitalizations in the United States.

2.2. Study population

Inclusion criteria included adults (≥18 years) with EGS diagnoses (AAST-defined ICD-9 codes)[13] and emergent admissions who needed surgery. EGS diagnoses were defined according to the AAST EGS classification, which includes conditions requiring urgent surgical evaluation, such as appendicitis, bowel obstruction, perforated viscus, intra-abdominal infection, and other acute surgical pathologies. A detailed list of ICD-9 diagnostic codes used to define EGS conditions is provided in Table S1.

Figure 1 shows the flowchart of patients' inclusion and exclusion criteria. The primary exposure was TTO (days from admission to surgery), and the outcome was in-hospital mortality. The study was approved by the New York Medical College Institutional Review Board.

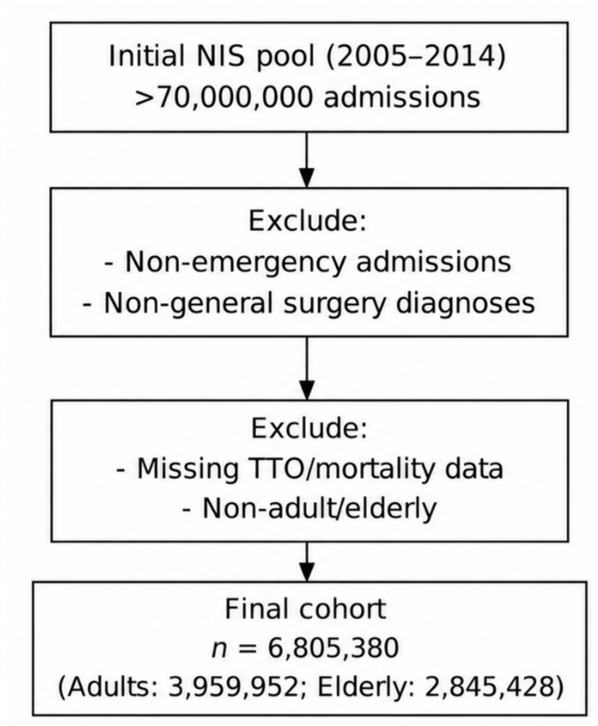

Figure 1. Flowchart of patient inclusion/exclusion

2.3. Variables

The following information was extracted from the database: demographic variables (age, sex, race), income, insurance type (private, Medicare, Medicaid, self-pay, no charge, and other), hospital location (rural, urban: non-teaching, urban: teaching), hospital length of stay, invasive diagnostic/surgical procedures, and comorbidities, such as heart diseases, diabetes, fluid/electrolyte disorders, neurological disorders, immunodeficiencies, alcohol abuse, drug abuse, musculoskeletal disorders, weight loss, and depression. A modified frailty index was used to evaluate patient vulnerability, with one point assigned for each of the following comorbidities: diabetes, heart failure, hypertension, chronic obstructive pulmonary disease (COPD), and dependent functional status.

2.4. Statistical analysis

Continuous variables are reported as means (standard deviation [SD]) due to the large sample size, which ensures normality of the sampling distribution per the central limit theorem. Sensitivity analyses using non-parametric tests (e.g., Mann–Whitney U) yielded identical conclusions ($p < 0.001$). Categorical variables are presented as frequencies and percentages. We tested normality using histograms and the Kolmogorov–Smirnov test. Chi-square and Student's *t*-tests were used to compare the categorical and continuous variables, respectively. The primary outcome of the study was in-hospital mortality. The primary exposure variable was TTO, defined as the number of days between hospital admission and the first surgical intervention. Ninety-five percent of procedures were done within the first seven days of admission. Univariable logistic regression analyses were performed for all candidate predictor variables before multivariable model construction. Crude odds ratios (ORs), 95% confidence intervals (CIs), and *p*-values were calculated. Variables demonstrating statistical significance ($p < 0.10$) or considered clinically relevant based on previous EGS literature were considered for inclusion in the final multivariable logistic regression models. Complete univariable results are presented in Table S2. Statistical analyses were performed using R version 4.3.1 (R Foundation for Statistical Computing, Austria).

2.5. Diagnosis-specific analyses

Because EGS encompasses a heterogeneous group of conditions with different pathophysiology and urgency of treatment, additional diagnosis-specific analyses were performed. Multivariable logistic regression models were repeated within major diagnostic categories to evaluate whether the association between TTO and in-hospital mortality remained consistent across different disease entities. These analyses included common EGS diagnoses such as appendicitis, bowel obstruction, perforated viscus, pancreatitis, and other acute abdominal pathologies.

3. Results

A total of 6,805,380 patients were included, of which 54% were females, and 43% underwent surgery. Over the 10 years of the study period, 1.7% died, of whom 52.5% were females. The cohort included adult (18–64 years) and elderly (≥65 years) patients admitted with EGS diagnoses. In total, 3,959,952 non-elderly adult patients, defined as adults 18–64 years old, were included in this study. A total of 50.5% were females with a mean age of 44.9 (SD: 12.7) years, similar to males (45.2 [SD: 12.4] years). In total, 2,845,428 elderly patients, defined as >65 years old, were included in this study. A total of 58.5% were female, with a mean age of 79 (SD: 8) years, which was two years older than the mean (SD) age of males. Univariable logistic regression analyses identified age, male sex, increasing frailty burden, and longer TTO as significant predictors of in-hospital mortality in both adult and elderly cohorts. Additional associations were observed for race, insurance status, income quartile, and hospital location. Detailed crude odds ratios and confidence intervals are presented in Table S2. Demographic variables, hospital characteristics, and comorbidity profiles were compared between survivors and non-survivors. Patients who died during hospitalization were generally older, had higher frailty scores, and experienced longer hospital length of stay (HLOS) compared with survivors.

3.1. Adult patients

A total of 25,931 adult patients (0.65%) died during the study period, of whom 10,781 were female (0.5% mortality rate), and 15,150 were male (0.8% mortality rate). The mean (SD) HLOS was 4.4 (SD: 5.4) days in surviving patients and 11.4 (SD: 17.7) days in deceased patients ($p < 0.001$). Mean (SD) modified frailty index out of 5 was 0.84 (SD: 1.00) and 1.52 (SD: 1.10), respectively ($p < 0.001$). Forty-three percent of the patients underwent surgery. The mean TTO was 1.34 days, and 95% of patients underwent surgery within the first seven days after admission. The mortality rate of the patients who underwent surgery was 0.7%. The multivariable logistic regression analysis of the patients who underwent surgery revealed TTO as a significant risk factor for mortality, with an OR of 1.058 (Table 1). Figure 2 compares mortality risk by TTO between adults and elderly patients. Logistic regression modeling demonstrated a progressive increase in mortality risk with each additional day of delay in surgical intervention. This association remained statistically significant after adjustment for age, sex, frailty, and major comorbidities. The relationship between TTO and mortality demonstrated an approximately linear increase across the observed time intervals, supporting the trend illustrated in Figure 2.

The logistic regression model of the subgroups of patients with a primary general surgery diagnosis revealed TTO as a significant risk factor for mortality in most scenarios. The examples for TTO for some of the EGS admissions were as follows: acute gastric ulcer (OR = 1.135, 95% CI: 1.046–1.231, $p < 0.001$), pseudocyst of pancreas (OR = 1.089, 95% CI: 1.058–1.122, $p < 0.001$), chronic duodenal ulcer (OR = 1.072, 95% CI: 1.040–1.105, $p < 0.001$), malignant neoplasm of rectum and rectosigmoid junction (OR = 1.072, 95% CI: 1.044–1.101, $p < 0.001$), acute pancreatitis (OR = 1.071, 95% CI: 1.062–1.080, $p < 0.001$), malignant neoplasm of colon (OR = 1.070, 95% CI: 1.045–1.096, $p < 0.001$), empyema (OR = 1.049, 95% CI: 1.017–1.081, $p < 0.002$), and ventral hernia (OR = 1.030, 95% CI: 1.001–1.060, $p < 0.04$).

Other risk factors of mortality included age, male sex, and frailty. Figure 3 compares the mortality rates by age and frailty. Overall, every one-year increase in the age of

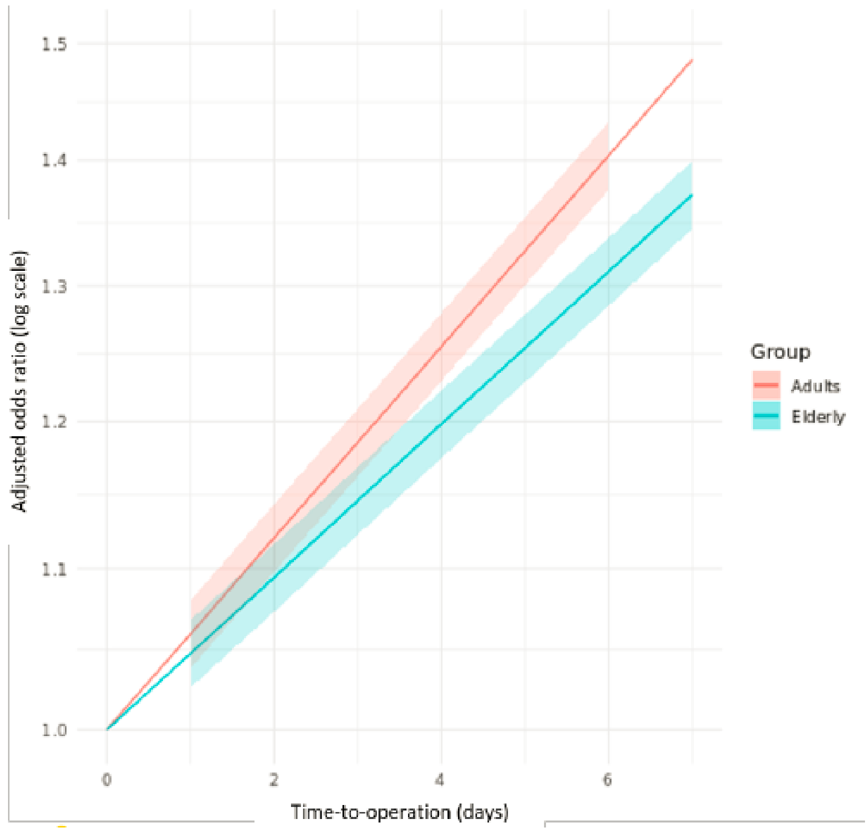

Figure 2. Comparison of mortality risk by time-to-operation (TTO) between adults and elderly patients

adult patients increased the odds of mortality by about 6%. Every additional comorbidity of the modified frailty index (diabetes, heart failure, hypertension, COPD, and dependent functional status) increased the odds of mortality by about 50% among adults. A total of 1,046,711 adult patients had no recorded comorbidities, of whom 59% underwent surgery. In this subgroup of adult patients, regression modelling demonstrated that each additional day of delay to surgery was associated with more than a twofold increase in the odds of mortality (Table 1).

3.2. Elderly patients

A total of 89,597 elderly patients (3.15%) died during the study period, of whom 49,868 were female (3% mortality rate), and 39,729 were male (3.4% mortality rate). Mean (SD) HLOS was 5.7 (SD: 5.8) days in surviving patients and 9.0 (SD: 11.9) days in deceased ones ($p < 0.001$). The mean (SD) modified frailty index out of 5 was 1.66 (SD: 1.09) and 1.88 (SD: 1.17), respectively ($p < 0.001$). One-third of patients underwent surgery. The mean TTO was two days, and 95% of patients underwent surgery within the first eight days after admission. The mortality rate of patients who underwent surgery was 4.2%. The multivariable logistic regression analysis on patients who underwent surgery revealed that TTO was a significant predictor of mortality, with an OR of 1.046 (Table 2). Figure 2 compares mortality risk by TTO between adults and elderly patients. When the same model was built on subgroups of patients with different primary diagnoses, TTO remained a significant predictor of mortality in most observations. Diagnosis-specific trends are presented in Table 3. The strongest association was observed among patients with intestinal fistulas. In elderly patients admitted emergently with intestinal fistulas, delaying surgery for more than three days, compared with ≤2 days, was associated with a twofold increase in mortality risk. Other examples for TTO for some of the EGS admissions were as follows: pneumothorax (OR = 1.131, 95% CI: 1.083–1.181, $p < 0.001$), gastritis with hemorrhage (OR = 1.128, 95% CI: 1.061–1.20, $p < 0.001$), hemorrhoids (OR = 1.126, 95% CI: 1.058–1.199, $p < 0.001$), neuroendocrine tumors (OR = 1.124, 95% CI: 1.032–1.223, $p < 0.007$), acute gastric ulcer (OR = 1.100, 95% CI: 1.040–1.163, $p < 0.001$), phlebitis and thrombophlebitis (OR = 1.094, 95% CI: 1.011–1.185, $p < 0.03$), acute pancreatitis (OR = 1.088, 95% CI: 1.077–1.100, $p < 0.001$), chronic duodenal ulcer (OR = 1.086, 95% CI:

Table 1. Backward multivariable logistic regression analysis of adult patients

Variable	Adult patients with operation and comorbidity, OR (95% CI)	*p*	Adult patients with operation and no comorbidity, OR (95% CI)	*p*
Age (years)	1.062 (1.059, 1.064)	<0.001	1.113 (1.102, 1.25)	<0.001
Sex (female)	0.699 (0.673, 0.727)	<0.001	0.518 (0.418, 0.642)	<0.001
Modified frailty index score	1.534 (1.509, 1.561)	<0.001	NA	
Time-to-operation (days)	1.058 (1.054, 1.061)	<0.001	1.135 (1.115, 1.156)	<0.001
Race/insurance/income quartile/ hospital location	Removed via backward elimination		Removed via backward elimination	

Abbreviations: CI: Confidence interval; OR: Odds ratio.

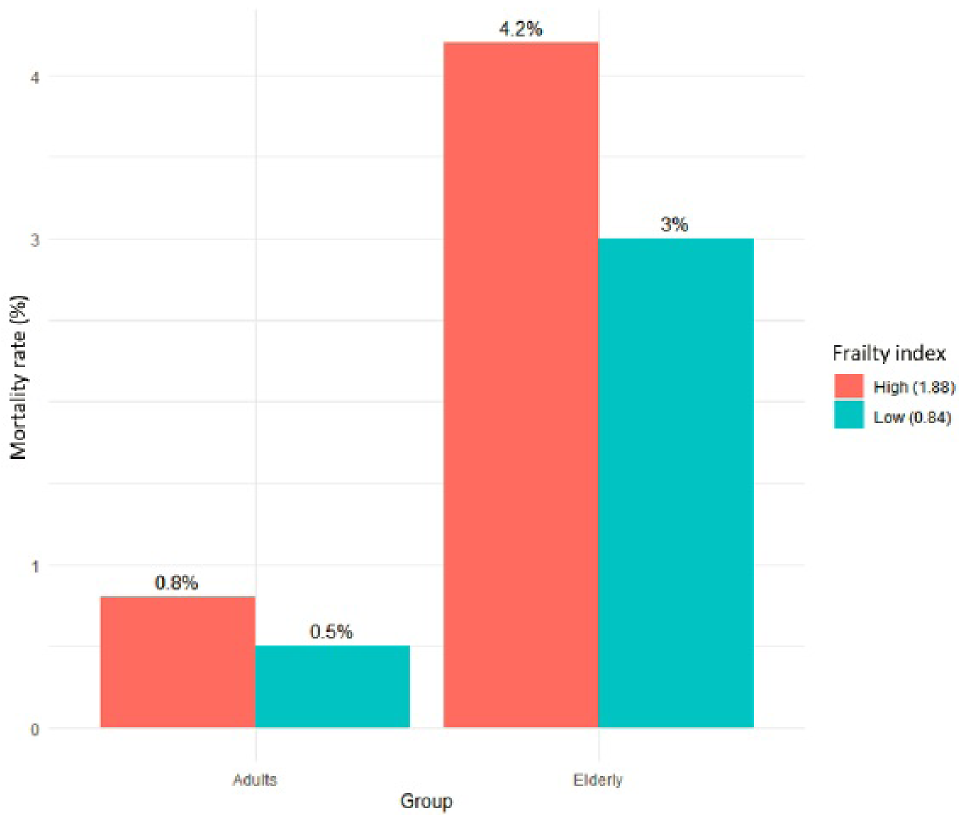

Figure 3. Hospital mortality rates by age and frailty. Patients were stratified by age group (adult: 18–64 years; elderly: ≥65 years) and by frailty burden using the modified 5-item frailty index (mFI–5). Frailty scores ranged from 0 to 5. Low frailty was defined as an mFI–5 score of 0–1 and high frailty as an mFI–5 score ≥ 2. Higher frailty scores indicate greater comorbidity burden and physiologic vulnerability.

1.062–1.111, $p < 0.001$), malignant neoplasm of rectum and rectosigmoid junction (OR = 1.085, 95% CI: 1.062–1.108, $p < 0.001$), ventral hernia (OR = 1.08, 95% CI: 1.05–1.11, $p < 0.001$), malignant neoplasm of colon (OR = 1.056, 95% CI: 1.042–1.069, $p < 0.001$), and empyema (OR = 1.037, 95% CI: 1.008–1.067, $p < 0.001$).

Other risk factors of mortality were age, male sex, and frailty. Figure 3 compares the mortality rates by age and frailty. Overall, every one-year increase in age among elderly patients increased the odds of mortality by about 5% (Table 2). Among the primary diagnoses, the most significant impact on mortality of elderly patients vs. adults was observed in acute appendicitis, regional enteritis, and gastroparesis (Table 3). Every additional comorbidity of the modified frailty index (diabetes, heart failure, hypertension, COPD, and dependent functional status) increased the odds of mortality by 20%. A total of 148,284 elderly patients had no recorded comorbidities, of whom 39% underwent surgery. Regression modelling of this patient subgroup showed that each additional day of surgical delay doubled the odds of mortality (Table 2).

Table 2. Backward multivariable logistic regression analysis of elderly patients

Variable	Elderly patients with operation and comorbidity, OR (95% CI)	*p*	Elderly patients with operation and no comorbidity, OR (95% CI)	*p*
Age (years)	1.049 (1.048, 1.051)	<0.001	1.089 (1.081, 1.097)	<0.001
Sex (female)	0.856 (0.838, 0.875)	<0.001	0.909 (0.807, 1.022)	0.110
Modified frailty index score	1.211 (1.199, 1.223)	<0.001	NA	
Time-to-operation (days)	1.046 (1.043, 1.048)	<0.001	1.093 (1.075, 1.112)	<0.001
Race/insurance/income quartile/ hospital location	Removed via backward elimination		Removed via backward elimination	

Abbreviations: CI: Confidence interval; OR: Odds ratio.

Table 3. Summary of findings by individual diagnoses and ICD-9 code

Reference	Mortality rate	TTO	OR for TTO/delayed operation	Significant findings	ICD-9 code
Levy *et al.*[15]	4.8% (rectosigmoid malignancy)	Not specified	OR 1.93 (cardiovascular disease)	Respiratory/cardiovascular comorbidities were top mortality predictors in rectal cancer	154.1 (Rectosigmoid cancer)
Hirani *et al.*[16]	2.7% (early surgery) vs. 6.1% (delayed surgery) in elderly	Early: ≤2 days; Delayed: >3 days	OR 2.26 (delayed vs. early surgery)	Delaying surgery beyond 3 days in elderly with intestinal fistulas doubled mortality risk	537.4 (Intestinal fistula)
Thomas *et al.*[17]	4.5% (elderly) vs. 1.7% (adults)	Not specified	OR 1.02 per day (estimated)	Age, comorbidities, and surgical delays were critical mortality predictors for intestinal fistulas	537.4 (Intestinal fistula)
Latifi *et al.*[19]	4.2% (elderly)	Mean TTO: 2 days	OR 1.046 per day	Delayed operation increased mortality risk in elderly with ventral hernias. Frailty and male sex were additional risk factors	553.3 (Ventral hernia)
Smiley *et al.*[20]	0.7% (adults)	Mean TTO: 1.34 days (deceased) vs. 0.81 days (survivors)	OR 1.058 per day	Delayed operation, male sex, and gangrene increased mortality in adults with ventral hernias	553.3 (Ventral hernia)
McGuirk *et al.*[21]	8.8% increase in mortality per day of delay (elderly)	Optimal HLOS: 3–7 days; beyond 7 days increased mortality by 6.7%/ day	OR 1.088 per day (delayed surgery)	Early surgical intervention (< 7 days) reduced mortality in elderly with acute pancreatitis	577.0 (Acute pancreatitis)
Ladinsky *et al.*[22]	5 times higher in elderly vs. non-elderly	Non-operative management linked to higher mortality	OR 0.49 (surgery as protective)	Non-operative management of anorectal abscesses in elderly increased mortality	566 (Anorectal abscess)
O'garro *et al.*[23]	2.5 times higher in elderly vs. adults	Not specified	OR 2.50 (elderly vs. adults)	Elderly with acute intestinal vascular insufficiency had higher mortality; age, male sex, and comorbidities were key risks	557.0 (Acute vascular insufficiency)
Lee *et al.*[24]	Predictors: TTO, frailty, comorbidities	TTO significantly associated with mortality	OR 1.12 per day (estimated)	Frailty and delayed surgery increased mortality in non-elderly adults with rhabdomyolysis	728.88 (Rhabdomyolysis)

(cont'd...)

Table 3. (*Continued*)

Reference	Mortality rate	TTO	OR for TTO/delayed operation	Significant findings	ICD-9 code
Lo *et al.*[25]	Surgery reduced mortality (protective factor)	Not specified	OR 0.50 (surgery vs. non-operative)	Longer hospital stays increased mortality risk (OR 1.02/day), while surgery reduced odds by 50% in patients with hematochezia	578.1 (Hematochezia)
Khandehroo *et al.*[26]	12 times higher in geriatric vs. adults	Not specified	OR 12.0 (geriatric vs. adults)	Female sex, prolonged hospital stays, and non-operative management increased mortality in geriatric patients with regional enteritis	555.9 (Regional enteritis)
Patel *et al.*[27]	3.5 times higher in elderly vs. adults	Not specified	OR 3.50 (elderly vs. adults)	Elderly with umbilical hernias had significantly higher mortality; frailty and delayed care contributed to poor outcomes	551.9 (Umbilical hernia)
Elgar *et al.*[28]	4 times higher with age	Longer TTO linked to mortality	OR 1.04 per day (estimated)	Age, frailty, and delayed surgery increased mortality in patients with paralytic ileus	560.1 (Paralytic ileus)
Levy *et al.*[29]	3% (elderly) vs. 0.8% (adults)	Not specified	OR 1.05 per day (estimated)	Frailty and delayed surgery were key mortality predictors in emergency admissions for hemorrhoids	455.6 (Hemorrhoids)
Elgar *et al.*[30]	Frailty and TTO increased mortality	Longer TTO associated with mortality	OR 1.10 per day	Frailty (OR 1.5), age, and delayed surgery predicted mortality in patients with intestinal fistulas, perforations, or angiodysplasia	569.83 (Perforation)
Hirani *et al.*[31]	7 times higher in geriatric vs. adults	Not specified	OR 7.00 (geriatric vs. adults)	Geriatric patients with emergent gastroparesis had significantly higher mortality; frailty and comorbidities were critical risks	536.3 (Gastroparesis)
Idris *et al.*[32]	Higher in elderly	Delayed surgery increased risk	OR 1.135 per day	Delayed operation, frailty, and comorbidities predicted mortality in acute gastric ulcer patients	531.00 (Acute gastric ulcer)
Lin *et al.*[33]	Higher with frailty and TTO	Delayed TTO increased mortality	OR 1.08 per day (estimated)	Chronic duodenal ulcer mortality linked to age, frailty, and delayed intervention	532.70 (Chronic duodenal ulcer)
Goud *et al.*[34]	Increased with TTO (OR 1.072/day)	Mean TTO: 1.5 days (survivors) vs. 2.1 days (deceased)	OR 1.072 per day	Each day of delay in surgery for gastrojejunal ulcers increased mortality risk by 7.2%	534.00 (Gastrojejunal ulcer)
Hirani *et al.*[35]	22 times higher in geriatric vs. non-geriatric	Not specified	OR 22.0 (geriatric vs. non-geriatric)	Geriatric appendicitis had dramatically higher mortality; delayed diagnosis and frailty were key contributors	540.9 (Appendicitis)
McGuirk *et al.*[36]	11.2% (non-elderly)	Optimal TTO: <48 hours	OR 1.15 per day (delayed surgery)	Early surgery (<48h) reduced mortality in non-elderly acute pancreatitis; frailty amplified risk	577.0 (Acute pancreatitis)
Lobao *et al.*[37]	32% (elderly)	Emergency surgery associated with lower mortality	OR 0.62 (surgery vs. non-operative)	Ruptured AAA: Longer HLOS and emergency surgery reduced mortality in elderly	441.3 (Ruptured Abdominal Aortic Aneurysm)
Levy *et al.*[38]	6.1% (tracheostomy complications)	Not specified	OR 1.21 (frailty per point)	Frailty and sepsis were key mortality drivers in tracheostomy emergencies	519.00 (Tracheostomy complication)

(*cont'd...*)

Table 3. (*Continued*)

Reference	Mortality rate	TTO	OR for TTO/delayed operation	Significant findings	ICD-9 code
Levy *et al.*[39]	8.3% (arterial embolism/ thrombosis)	Not specified	OR 1.18 (per day of delay)	Delayed revascularization increased mortality in arterial embolism/thrombosis	444.22 (Arterial embolism/ thrombosis)
Levy *et al.*[40]	5.7% (empyema)	Not specified	OR 1.12 (per day of delay)	Surgical drainage reduced mortality by 40% in empyema cases	510.9 (Empyema)
Montes *et al.*[41]	Not specified	Delayed TTO linked to mortality	OR 1.09 per day (estimated)	Frailty, delayed surgery, and comorbidities predicted mortality in emergent liver abscess cases	572.0 (Liver abscess)
Thaker *et al.*[42]	Higher in elderly	Longer TTO associated with mortality	OR 1.06 per day (estimated)	Intestinal adhesive obstruction mortality linked to delayed surgery and frailty	560.81 (Intestinal obstruction)
Krishnan *et al.*[43]	Higher in elderly	Not specified	OR 2.10 (elderly vs. adults)	Diaphragmatic hernia mortality driven by age, frailty, and non-operative management	553.3 (Diaphragmatic hernia)

Abbreviations: AAA: Abdominal aortic aneurysm; HLOS: Hospital length of stay; ICD-9: International Classification of Diseases, Ninth Revision; OR: Odds ratio; TTO: Time-to-operation.

4. Discussion

Dedicated EGS service models have evolved over the past two decades as part of the broader acute care surgery paradigm, integrating trauma surgery, surgical critical care, and EGS into a unified system. These services typically involve dedicated surgical teams, protected access to operating rooms, and standardized care pathways. Several studies have demonstrated that such models can reduce operative delays, improve timeliness of care, and decrease complication rates. Our findings provide additional population-level evidence supporting the continued development of dedicated EGS systems.

A key finding was the identification of TTO as a critical factor influencing mortality in both cohorts, but an unexpected finding was high mortality among patients with no recorded comorbidities. In adults, each day of delay in surgical intervention is correlated with an increased odds of 5.8% in mortality. The observed mortality rate of 0.7% among operated adult patients adds a layer of complexity, suggesting that when surgery is necessary, delays may adversely influence outcomes. For the elderly cohort, the mortality rate was higher at 3.15%, with female patients demonstrating a slightly lower mortality rate (3%) than their male counterparts (3.4%). These findings point to the compounded risks that elderly patients face, particularly those characterized by higher frailty indices and prolonged hospital stays (mean HLOS of 9.0 days for deceased individuals). The increased odds of 4.6% in mortality for every one-day delay in surgical intervention in elderly patients further emphasize the critical need to minimize delays in surgical interventions in this vulnerable population. Overall, these findings align with the results of previous individual studies performed by our group and others (Table 3), demonstrating that timely surgery is essential in preventing complications such as sepsis, organ failure, or worsening disease states. Most of these studies have been conducted using the NIS database.[14]

The pronounced delay in TTO among patients with no recorded comorbidities is particularly striking. This subgroup, seemingly at lower risk, experienced more than twofold mortality odds with each day of delay (Adults: OR: 1.135; Elderly: OR: 1.093). This suggests that the detrimental effects of surgical delay are not solely mediated by pre-existing chronic conditions but may be directly related to the progression of the acute surgical disease itself, such as the development of sepsis, gangrene, or multi-organ dysfunction. It implies that timely intervention is a critical determinant of survival even for otherwise healthy individuals facing an EGS condition.

In a cohort study[15] involving 10,918 adults and 12,696 elderly patients with rectosigmoid carcinoma, the critical mortality risk factors identified for the adult population included time to surgical intervention, respiratory pathology (OR = 2.83), and cardiovascular disease (OR = 1.93). In contrast, extended hospital length of stay (OR = 1.02) was a significant predictor in the elderly cohort. Hirani *et al.*[16] examined 34,853 elderly patients with intestinal fistulas, elucidating the deleterious impact of surgical delays on mortality, with those delaying surgery beyond three days exhibiting mortality rates of 6.1% compared to 2.7% for those undergoing intervention within two days. In a subsequent combined analysis of 7,377 patients with intestinal fistulas, significant mortality determinants included age, comorbidities, and surgical delays, revealing elevated mortality rates of 4.5% among elderly patients compared with 1.7% in adults. When combining adult and elderly cohorts, a study by Thomas *et al.*[17] revealed that increased hospital length of stay, advancing age, and delays in the first surgical procedure were significantly associated with higher mortality risk, especially among the elderly. This analysis of 7,377 patients, utilizing the NIS Database from 2004 to 2014, demonstrated mortality rates of 4.5% for the elderly and 1.7% for adults. These findings emphasize the critical impact of comorbidities and surgical delays, underscoring the necessity for timely intervention to mitigate mortality in this vulnerable population.

In a prospective observational study by Saar *et al.*[18] that examined the link between the delay from symptom onset to appendectomy and postoperative complications in 266 adult patients, 83.1% underwent laparoscopic surgery and found that longer delays were associated with increased complications, prolonged surgery duration, and longer hospital stays, highlighting the necessity for prompt appendectomy in acute appendicitis. Latifi *et al.*[19] investigated in-hospital mortality risk factors in elderly patients admitted emergently with ventral hernias by analyzing data from 33,700 cases between 2005 and 2014. The findings indicated that delayed operations significantly increased mortality rates in this population. In another study, Smiley *et al.*[20] analyzed 48,539 adults with emergently admitted ventral hernias and found that deceased patients averaged 1.34 days TTO compared to 0.81 days for survivors, highlighting the critical need for timely surgical intervention. The consistency of our findings across a vast spectrum of EGS diagnoses, as detailed in Table 3, underscores the universality of time as a risk factor. From inflammatory conditions like acute pancreatitis to mechanical issues like intestinal obstruction and hernias, the pattern holds: delay may increase the risk. This broad applicability moves the concept of TTO from a condition-specific concern to a fundamental principle of EGS care, akin to the early administration of antibiotics in sepsis or source control in intra-abdominal infection. EGS encompasses a broad spectrum of diseases with varying pathophysiology and urgency of operative intervention. For example, conditions such as perforated viscus or strangulated obstruction require immediate surgery, whereas others, such as acute pancreatitis or selected cases of appendicitis, may initially be managed non-operatively. To address this heterogeneity, we performed diagnosis-specific analyses, which demonstrated that the association between delayed TTO and mortality remained significant across many individual EGS conditions. Nevertheless, the heterogeneous nature of EGS diagnoses remains an inherent limitation of large administrative database studies.

Our previous research on several EGS conditions has demonstrated that delays in surgical intervention are associated with increased morbidity and mortality rates (Table 3). The key trends associated with these studies are as follows: each day of surgical delay increased mortality risk by 5–13.5%, depending on the condition and age. Adults' OR ranged from 1.04–1.135 per day of delay, and elderly OR ranged from 1.046–1.088 per day of delay. Elderly patients consistently faced 2–22 times higher mortality compared to adults. Higher frailty scores increased mortality risk across all cohorts (ORs of 1.2–1.5). Surgery worked as a protective factor; operative management reduced mortality by 3–50% in most conditions. System-level delays in surgical care are linked to worse patient outcomes, including increased mortality and complications. Structural inefficiencies, such as delayed diagnostics or operating room access, disproportionately affect emergency and high-risk surgeries.[44-49] The mechanisms by which delay translates to mortality are multifactorial. Prolonged TTO allows for the progression of physiologic insults, increasing the likelihood of patients arriving in the operating room in a state of irreversible shock or with established organ failures. This aligns with the concept of "failure to rescue," where delays in recognizing clinical deterioration or in executing definitive care led to preventable deaths, a significant concern in EGS populations.[50-53] Furthermore, the amplifying effect of frailty, even when measured by a simple 5-item index, highlights that physiological reserve is a key moderator in a patient's ability to withstand the dual stressors of acute illness and operative delay.[54-58]

Recent research has spurred several quality improvement initiatives in EGS, leading to the development of national standards and verification processes. Key efforts include the establishment of registries, the creation of protocols and evidence-based guidelines, the implementation of disease-specific approaches, regional collaborations, and a focus on high-risk procedures such as exploratory laparotomy and on special populations such as the elderly.[59-67] In addition, the ACS and the AAST have initiated efforts to establish dedicated EGS services, recognizing the need for specialized care in this area. This initiative aims to enhance patient outcomes by expanding access to focused surgical services tailored to the complexities of emergency surgery. Elderly patients face higher risks of poor surgical outcomes due to comorbidities and functional decline, not just age. Comprehensive geriatric assessments and multidisciplinary care models are critical for addressing their complex needs.[59-67] The establishment of dedicated EGS services is a direct response to these systemic challenges. By creating structured clinical pathways, dedicated operating room access, and specialized multidisciplinary teams, these services aim to address the modifiable root causes of TTO delays directly. Early evidence suggests that such models can improve outcomes; for instance, dedicated acute care surgery services have been associated with reduced TTO and lower complication rates for common EGS conditions.[68-72]

This comprehensive study examined the correlation between TTO and hospital mortality by analyzing the largest cohort of admitted patients for EGS to date. Another strength of this study, in addition to the sample size, which provided robust statistical power and enhanced the validity of its findings, was its broad representation of EGS conditions and demographics. Moreover, advanced statistical methods, including multivariable logistic regression and generalized additive models, were used to evaluate nonlinear associations between mortality and continuous variables for each diagnosis, yielding nuanced insights into the complex relationship between surgical delay and mortality risk.

However, this study had some limitations—a retrospective analysis based on observational data, including the potential for unmeasured confounding. The limitations of NIS data include insufficient granularity in patient conditions, making it difficult to accurately assess surgical urgency. The dataset may include non-emergent cases, potentially skewing results on the impact of TTO on mortality. Additionally, it lacks outcome data for patients who were not operated on, leading to gaps in understanding the implications of surgical delays. The reasons for delays, such as resource constraints and staffing issues, are also unrecorded. Another limitation relates to the heterogeneity of EGS diagnoses included in the analysis. To partially address this issue, diagnosis-specific analyses were conducted to assess whether the relationship between TTO and mortality remained consistent across disease categories. These conditions vary widely in clinical course, urgency of intervention, and indications for operative management. Although diagnosis-specific analyses were performed to partially address this limitation, administrative databases such as the NIS lack the clinical granularity needed to determine the precise urgency of surgery in individual cases.

It is important to acknowledge that immediate surgical intervention is not universally indicated in all EGS cases. Contemporary management strategies for selected patients with acute appendicitis, cholecystitis, or mechanical bowel obstruction may include initial non-operative management or observation. Therefore, the observed association between TTO and mortality should not be interpreted as implying that immediate surgery is always required, but rather that system-related delays when surgery is indicated may adversely impact outcomes. These challenges underscore the need for further refinement of NIS data to improve its utility for clinical research and decision-making.

5. Conclusion

Delayed TTO was associated with increased mortality among patients undergoing EGS in this national dataset. While not all EGS conditions require immediate surgical intervention, minimizing system-related delays when surgery is indicated may improve patient outcomes. These findings support ongoing efforts to optimize the delivery of emergency surgical care, including the development of dedicated EGS service models. Hospitals should prioritize TTO and implement dedicated EGS services and protocols that minimize delays in surgical care by establishing EGS-dedicated programs initiated by AAST and ACS, thereby potentially improving outcomes for critically ill patients at initial admission or readmission, when failure to rescue becomes a major factor in mortality. Future research should address the factors and barriers to delays in TTO, real-time TTO tracking, and investigate strategies to optimize and streamline EGS workflows. These results further support the recent initiative by ACS/AAST to establish dedicated EGS services, which reduces delays in TTO.

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Conflict of interest

The authors declare that they have no affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

Author contributions

Conceptualization: All authors
Formal analysis: Abbas Smiley
Investigation: All authors
Methodology: All authors
Writing–original draft: All authors
Writing–review & editing: All authors

Ethics approval and consent to participate

The study was approved by the Ethics Committee of New York Medical College (Approval no. 14177).

Consent for publication

The study was conducted on a publicly available dataset. There was no need to obtain consent.

Availability of data

Data are available from the corresponding author upon reasonable request.

Further disclosure

AI-assisted tools (ChatGPT-4) were used to generate R code templates and refine language; all outputs were human-verified.

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