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ORIGINAL ARTICLE

Morbidity and Mortality After Gastrectomy: Identification of Modifiable Risk Factors

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Abstract

Background Morbidity after gastrectomy remains high. The potentially modifiable risk factors have not been well described. This study considers a series of potentially modifiable patient-specific and perioperative characteristics that could be considered to reduce morbidity and mortality after gastrectomy.

Methods This retrospective cohort study includes adults in the ACS NSQIP PUF dataset who underwent gastrectomy between 2011 and 2013. Sequential multivariable models were used to estimate effects of clinical covariates on study outcomes including morbidity, mortality, readmission, and reoperation.

Results Three thousand six hundred and seventy-eight patients underwent gastrectomy. A majority of patients had distal gastrectomy ($N = 2{,}799$, 76.1 %) and had resection for malignancy ($N = 2{,}316$, 63.0 %). Seven hundred and ninety-eight patients (21.7 %) experienced a major complication. Reoperation was required in 290 patients (7.9 %). Thirty-day mortality was 5.2 %. Age (OR = 1.01, 95 % CI = 1.01–1.02, $p = 0.001$), preoperative malnutrition (OR = 1.65, 95 % CI = 1.35–2.02, $p < 0.001$), total gastrectomy (OR = 1.63, 95 % CI = 1.31–2.03, $p < 0.001$), benign indication for resection (OR = 1.60, 95 % CI = 1.29–1.97, $p < 0.001$), blood transfusion (OR = 2.57, 95 % CI = 2.10–3.13, $p < 0.001$), and intraoperative placement of a feeding tubes (OR = 1.28, 95 % CI = 1.00–1.62, $p = 0.047$) were independently associated with increased risk of morbidity. Association between tobacco use and morbidity was statistically marginal (OR = 1.23, 95 % CI = 0.99–1.53, $p = 0.064$). All-cause postoperative morbidity had significant associations with reoperation, readmission, and mortality (all $p < 0.001$).

Conclusions Mitigation of perioperative risk factors including smoking and malnutrition as well as identified operative considerations may improve outcomes after gastrectomy. Postoperative morbidity has the strongest association with other measures of poor outcome: reoperation, readmission, and mortality.

Keywords Gastrectomy · Morbidity · ACS NSQIP · Surgical outcomes · Gastric resection

Introduction

Surgical quality improvement is at the forefront of outcome initiatives at both institutional and national levels.[1–3] Advances in data collection and process management driven within the surgical community by the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) have led to increased awareness of perioperative morbidity and development of programs to improve patient-specific outcomes. Recent improvements in NSQIP include the addition of targeted modules for certain disease groups, including hepatobiliary, vascular, and colorectal among others, as well as more granular data abstraction to better highlight procedure-specific complications and risk factors.[4, 5] Despite data suggesting considerable morbidity,

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gastrointestinal operations have not been the focus of recent targeted NSQIP improvement.[6]

Medical treatments of peptic ulcer disease and endoscopic advances have changed the landscape of upper gastrointestinal surgery. At present, gastric operations are largely resections for cancer or a part of high-volume bariatric subspecialty. Despite this perception, gastrectomy remains an important and morbid general surgery operation.[7–11] A recent NSQIP study evaluating morbidity associated with gastrectomy for gastric cancer identified 5 % post-operative mortality after total gastrectomy—higher than current mortality after major hepatectomy or pancreaticoduodenectomy.[8, 12, 13]

From a perioperative perspective, the risks after gastrectomy have not been adequately explored. Institutional and registry data suggest an overall morbidity of approximately 20 % and increased risk of readmissions among patients who developed complications.[7, 10, 14, 15] The individual effects associated with specific and potentially modifiable risk factors remain poorly defined. This study considers a series of patient-specific and perioperative characteristics, including diagnosis, extent of resection, intra- and post-operative blood transfusion, and use of surgically placed feeding tubes, on post-operative morbidity and mortality after gastrectomy. We hypothesized significant effects of these important clinical covariates on post-operative outcomes and aimed to identify potentially modifiable risk factors.

Materials and Methods

Patient Selection, Characteristics, and Outcome Definitions

The current study used patient records obtained from the ACS NSQIP public use file (PUF). NSQIP is a nationally maintained database that contains aggregated, patient-level, Health Insurance Portability and Accountability Act (HIPAA) compliant data provided by participating hospitals. The University of Virginia Institutional Review Board (UVA IRB) for Health Sciences Research (HSR) has designated the NSQIP PUF as a public data set; however, since a partial merger between NSQIP PUF data and institutional data was planned to evaluate associations between gastrectomy and readmission, this study was reviewed and approved by the UVA HSR IRB (IRB-HSR no. 18610).

All adult patients (≥18 years of age) who underwent gastrectomy for benign and malignant pathology between 2011 and 2013 were included in this retrospective cohort study. Readmission data collection was started in 2011; as such, that year was selected as the beginning of the cohort. All UVA patients who had gastrectomy and required readmission were re-reviewed and merged with institutional data to facilitate data interpretation. Gastrectomy was defined according to the index operation using current procedural terminology (CPT) codes: total gastrectomy (43620, 43621, 43622) and distal gastrectomy (43631, 43632, 43633, 43634). Patients who had partial or wedge non-anatomic gastric resection and did not require gastrointestinal reconstruction were not included in this study. Indication for resection, defined by final post-operative diagnosis including pathologic confirmation, was stratified into malignant and benign diagnoses using the International Classification of Diseases, 9th revision (ICD-9) codes (Appendix).

The primary outcome was occurrence of 30-day morbidity. Composite all-cause 30-day morbidity was defined as the occurrence of one or more of the following NSQIP-defined variables: pneumonia, reintubation, failure to wean off the ventilator, renal insufficiency, renal failure, cardiac arrest, myocardial infarction, coma, stroke, sepsis, septic shock, fascial dehiscence, organ space infection, or venous thromboembolism (deep vein thrombosis and/or pulmonary embolism). Secondary outcome measures included mortality, readmission, and reoperation. Standard NSQIP definitions of 30-day readmission and mortality were used. Reoperation was defined as any return to the operating room related to the index procedure or to a complication related to the index procedure. Preoperative malnutrition was defined as a preoperative albumin of less than 3 g/dL and/or preoperative weight loss of greater than 10 % of body weight. Patients receiving intraoperative placement of feeding tubes concomitant with the index gastrectomy procedure were identified using CPT codes for gastrostomy (43830) and jejunostomy (44015). Perioperative blood transfusion was defined as any transfusion of one or more units of packed red blood cells given from the start time of the index procedure through 72 h postoperatively.

Data analysis

Summary data for the patient cohort were aggregated to describe the demographic and clinical factors including, age, sex, body mass index, race, ethnicity, diabetes, tobacco use, serum albumin, indication for resection (benign or malignant), American Society of Anesthesiologists (ASA) class, operative duration, blood transfusion, surgical feeding tube placement, post-operative morbidity, readmission, reoperation, and mortality. Univariable and multivariable logistic regression analyses were used to test the effect of clinical covariates on study outcomes: morbidity, reoperation, readmission, and mortality. For each multivariable model, variables from univariate analyses that were defined a priori to reach the <0.05 significance threshold were included in multivariable analysis. Multivariable models testing the associations between covariates and mortality were performed with and without the readmission variable. For the purposes of the logistic regression analysis, operative time was categorized at the median (median operative time = 194 min). STATA version 14.1 (StataCorp

LP, College Station, TX, USA) software was used for data management and statistical analysis.

Results

Patient Characteristics and Preoperative Risk Factors

A total of 3,678 patients underwent distal or total anatomic gastrectomy during the study period. A majority of patients had distal gastrectomy ($N = 2,799$, 76.1 %), and the remaining 879 patients (23.9 %) underwent total gastrectomy. A majority of patients ($N = 2,316$, 63.0 %) underwent resection for malignancy. Patient demographics and perioperative factors are summarized in Table 1. Intra- and post-operative blood transfusions were required in 22.7 % of the cohort. Surgically placed feeding tubes (including gastrostomy and jejunostomy) were used in 14.4 % of the patients. Seven hundred and ninety-eight patients (21.7 %) had one or more instances of major morbidity. Frequencies of post-operative NSQIP morbidities are summarized in Table 2. The two most common complications were organ space surgical site infection (7.1 %) and sepsis (6.8 %). Reoperation was required in 290 patients (7.9 %), and 447 patients (12.2 %) were readmitted within 30 days of discharge.

Estimates of Covariate Associations with Morbidity, Reoperation, and Readmission

Univariable and multivariable models were tested to estimate associations between demographic and clinical factors and post-operative morbidity (Table 3). Univariable analysis identified age, race, preoperative malnutrition, tobacco use, ASA class 4 and 5, total gastrectomy, benign indication for operation, perioperative blood transfusion, operative duration ≥ median, and placement of surgical feeding tube as associated with postoperative morbidity (all $p \leq 0.036$). After adjusting for significant demographic and clinical covariates, age (OR = 1.01, 95 % CI = 1.01–1.02, $p = 0.001$), preoperative malnutrition (OR = 1.65, 95 % CI = 1.35–2.02, $p < 0.001$), total gastrectomy (OR = 1.63, 95 % CI = 1.31–2.03, $p < 0.001$), benign indication for resection (OR = 1.60, 95 % CI = 1.29–1.97, $p < 0.001$), blood transfusion (OR = 2.57, 95 % CI = 2.10–3.13, $p < 0.001$), operative time ≥ median (OR = 1.43, 95 % CI = 1.18–1.73, $p < 0.001$), and intraoperative placement of a feeding tube (OR = 1.28, 95 % CI = 1.00–1.62, $p = 0.047$) were independently associated with postoperative morbidity. Associations between tobacco use and greater morbidity were marginal (OR = 1.23, 95%CI = 0.99–1.53, $p = 0.064$).

There was no difference in age ($p = 0.60$) or ASA class ($p = 0.070$) between patient cohorts who had surgically inserted feeding tubes and patients who had gastrectomy without placement of an intraoperative feeding tube. Patients who had intraoperative feeding tubes were more likely to have preoperative malnutrition (28.9 vs. 24.1 %, $p = 0.019$), total gastrectomy (50.6 vs. 19.4 %, $p < 0.001$), malignant diagnoses (71.7 vs. 61.5 %, $p < 0.001$), and perioperative blood transfusion (26.0 vs. 22.1 %, $p = 0.046$). Significantly greater proportion of patients with benign (non-malignant) indication for resection had higher preoperative ASA class 4/5 compared to patients with malignant diagnosis (17.6 vs. 7.7 %, respectively, $p < 0.001$).

Table 1 Study demographics

Patient demographics	$N = 3,678$
Age (years), median (IQR)	64 (54–74)
BMI (kg/m^2), median (IQR)	25.8 (22.2–30.3)
Sex, *N* (%)	
Male	1,835 (49.9)
Female	1,842 (51.1)
Race/ethnicity, *N* (%)	
White	2,097 (57.0)
Black	535 (14.6)
Hispanic	301 (8.2)
Asian or American Indian	419 (11.4)
Preoperative risk factors	
Preoperative malnutrition, *N* (%)	912 (24.8)
Diabetes, *N* (%)	694 (18.9)
Smoking, *N* (%)	821 (22.3)
ASA class, *N* (%)	
ASA 1	35 (0.95)
ASA 2	985 (26.8)
ASA 3	2,229 (60.6)
ASA 4	397 (10.8)
ASA 5	30 (0.82)
Gastrectomy, *N* (%)	
Distal gastrectomy	2,799 (76.1)
Total gastrectomy	879 (23.9)
Surgery indication, *N* (%)	
Malignant	2,316 (63.0)
Benign	1,362 (37.0)
Operative factors	
Blood transfusion, *N* (%)	834 (22.7)
Operative time (min), median (IQR)	194 (139–267)
Feeding jejunostomy, *N* (%)	530 (14.4)
Postoperative occurrences	
Composite morbidity, *N* (%)	798 (21.7)
Reoperation, *N* (%)	290 (7.9)
Readmission, *N* (%)	447 (12.2)
Mortality, *N* (%)	191 (5.2)

IQR interquartile range, *ASA* American Society of Anesthesiologists

Table 2 Top 15 causes of major morbidity as defined by NSQIP variables

	N	%
Organ/space SSI	259	7.05
Sepsis	250	6.80
Failure to wean from vent	242	6.58
Pneumonia	235	6.38
Septic shock	165	4.48
Unplanned reintubation	162	4.40
DVT requiring therapy	63	1.71
Acute renal failure	47	1.28
Fascial dehiscence	40	1.09
Myocardial infarction	37	1.01
Pulmonary embolism	30	0.82
Cardiac arrest	25	0.68
Renal insufficiency	24	0.65
CVA/stroke	19	0.52
Coma	4	0.11

SSI surgical site infection, *DVT* deep vein thrombosis, *CVA* cerebrovascular accident

Univariable and multivariable models testing the associations between clinical covariates and reoperation and readmission are summarized in Tables 4 and 5, respectively. After adjustment for covariates, tobacco use was the only preoperative risk factor associated with increased risk of reoperation (OR = 1.51, 95 % CI = 1.12–2.05, $p = 0.008$). Postoperative morbidity was strongly associated with reoperation (OR = 10.7, 95 % CI = 7.94–14.4, $p < 0.001$). The association between perioperative blood transfusion and risk of reoperation approached significance (OR = 1.30, 95 % CI = 0.96–1.76, $p = 0.088$). Age, reoperation, and all-cause morbidity (all $p \leq 0.003$) were independently associated with readmission after gastrectomy (Table 5).

Postoperative Mortality After Gastrectomy

Thirty-day mortality in the study population was 5.2 %. There was no difference in mortality after distal and total gastrectomy (5.0 vs. 5.7 %, respectively, $p = 0.45$). Univariable and multivariable analyses demonstrating associations between study covariates and mortality are summarized in Table 6. Univariable comparisons identified age, Hispanic ethnicity, preoperative malnutrition, ASA class 4 and 5, non-malignant indication for resection, blood transfusion, operative time less than the median, all-cause morbidity, and reoperation as significantly associated with mortality (all $p \leq 0.043$). After adjustment for covariates, age (OR = 1.04, 95 % CI = 1.03–1.06, $p < 0.001$), preoperative malnutrition (OR = 1.86, 95 % CI = 1.31–2.65, $p = 0.001$), blood transfusion (OR = 2.00, 95 % CI = 1.40–2.87, $p < 0.001$), all-cause morbidity (OR = 6.78, 95 % CI = 4.62–9.95, $p < 0.001$), and reoperation (OR 1.74, 95 % CI = 1.15–2.65, $p = 0.010$) were independently associated with mortality (Table 6).

The reported multivariable mortality model does not include the readmission variable. When included in the model, readmission is associated with decreased NSQIP-reported mortality (OR = 0.37, 95 % CI = 0.20–0.69, $p = 0.002$). Using the current NSQIP variable definition, the patient who is readmitted and dies within a 30-day period would not be reported as dead within the NSQIP PUF. To further explore association between readmission and mortality, all patients who had gastrectomy at our institution were examined. Of 42 institutional patients who had gastrectomy during the study period, none died within 30 days of operation; two (4.8 %) died within 90 days of operation. Further statistical analysis is not feasible.

Discussion

Gastrectomy remains the preferred surgical treatment option for many benign and malignant diseases affecting the upper gastrointestinal tract. Common indications for gastrectomy include malignancy (i.e., adenocarcinoma, gastrointestinal stromal tumors, selected neuroendocrine neoplasms, etc.) and recalcitrant peptic ulcer disease or one of its long-term sequelae such as bleeding, perforation, or stricture. Outcomes after gastrectomy in non-bariatric patients have arguably received less scrutiny than outcomes after hepatobiliary, pancreatic, or colorectal resections. At present, gastrectomy is not one of the NSQIP targeted modules, which has direct implications for limited data collection and less targeted areas for performance improvement.

Indeed, for targeted surgical procedure modules, operation-specific complications, such as anastomotic leaks, fistula, or postoperative ileus are identified using extended data collection. Without focused data collection, gastrectomy cases are not well represented among the larger population of complex abdominal cases and lack granular targeted-module data. Not surprisingly, and consistent with published data, surgical site infection and sepsis are the two most common metrics of NSQIP measured morbidity in this study.[16] The organ space SSI of 7.05 % is consistent with published rates of anastomotic leaks in recent literature ranging from 5 to 7 %; however, without targeted NSQIP data collection, the exact proportion of anastomotic leaks rather than other surgically-related causes of intra-abdominal infection cannot be defined precisely.[17–20]

NSQIP-reported mortality after gastrectomy is higher than mortality after major hepatectomy, pancreaticoduodenectomy, and esophagectomy.[12, 13, 21] Indeed, our study identified a 30-day mortality rate of 5.2 %. While some institutional studies have described 0 % mortality, database and multi-center collaborative studies consistently report significantly higher patient mortality.[9, 11, 22–28] A recent multi-center study from the US Gastric Cancer Collaborative of 447 sub-total resections

Table 3 30-Day morbidity after gastrectomy

Univariable			
Variable	OR	95 % CI	*p* value
Age	1.01	1.01–1.02	<0.001
BMI	1.01	1.00–1.02	0.20
Sex			
Female	1.00 (reference)		
Male	1.03	0.88–1.21	0.67
Race/ethnicity			
White	1.00 (reference)		
Black or African-American	0.67	0.53–0.86	0.001
Hispanic	0.67	0.49–0.92	0.013
Asian, NH, PI, AI, Alaskan	0.58	0.43–0.76	<0.001
Preoperative malnutrition			
Normal nutrition	1.00 (reference)		
Malnutrition	2.71	2.29–3.20	<0.001
Diabetes	1.05	0.89–1.28	0.65
Smoking	1.22	1.01–1.46	0.036
ASA class			
ASA class 1	1.00 (reference)		
ASA class 2	1.64	0.49–5.42	0.42
ASA class 3	2.74	0.83–8.97	0.097
ASA class 4	9.31	2.80–30.9	<0.001
ASA class 5	35.0	8.18–150.1	<0.001
Surgery type			
Distal gastrectomy	1.00 (reference)		
Total gastrectomy	1.52	1.28–1.81	<0.001
Surgical indication			
Malignant	1.00 (reference)		
Benign	1.67	1.42–1.95	<0.001
Transfusion	3.93	3.31–4.66	<0.001
Operative time			
Operative time < median	1.00 (reference)		
Operative time ≥ median	1.38	1.18–1.61	<0.001
Feeding tube	1.56	1.27–1.92	<0.001
Multivariable			
Variable	OR	95 % CI	*p* value
Age	1.01	1.01–1.02	0.001
Race/ethnicity			
White	1.00 (reference)		
Black or African-American	0.69	0.53–0.90	0.021
Hispanic	0.83	0.59–1.16	0.27
Asian, NH, PI, AI, Alaskan	0.85	0.62–1.15	0.29
Preoperative malnutrition			
Normal nutrition	1.00 (reference)		
Malnutrition	1.65	1.35–2.02	<0.001
Smoking	1.23	0.99–1.53	0.064
ASA class			
ASA class 1	1.00 (reference)		
ASA class 2	1.02	0.29–3.51	0.98
ASA class 3	1.46	0.43–5.01	0.55
ASA class 4	3.23	0.92–11.3	0.067
ASA class 5	14.5	2.77–76.2	0.002
Surgery type			
Distal gastrectomy	1.00 (reference)		
Total gastrectomy	1.63	1.31–2.03	<0.001
Surgical indication			
Malignant	1.00 (reference)		
Benign	1.60	1.29–1.97	<0.001
Transfusion	2.57	2.10–3.13	<0.001
Operative time			
Operative time < median	1.00 (reference)		
Operative time ≥ median	1.43	1.18–1.73	<0.001
Feeding tube	1.28	1.00–1.62	0.047

C statistic 0.74

Table 4 Reoperation after gastrectomy

Univariable			
Variable	OR	95 % CI	*p* value
Age	1.00	0.99–1.01	0.98
BMI	0.99	0.97–1.01	0.20
Sex			
Female	1.00 (reference)		
Male	1.06	0.83–1.35	0.64
Race/ethnicity			
White	1.00 (reference)		
Black or African-American	0.44	0.28–0.69	<0.001
Hispanic	0.81	0.52–1.27	0.36
Asian, NH, PI, AI, Alaskan	0.62	0.40–0.96	0.031
Preoperative Malnutrition			
Normal nutrition	1.00 (reference)		
Malnutrition	1.51	1.16–1.95	0.002
Diabetes	0.71	0.51–1.00	0.048
Smoking	1.55	1.19–2.02	0.001
ASA class			
ASA Class 1	1.00 (reference)		
ASA Class 2	2.17	0.29–16.1	0.45
ASA Class 3	2.90	0.39–21.3	0.30
ASA Class 4	4.68	0.63–34.9	0.13
ASA Class 5	10.3	1.19–89.8	0.034
Surgery type			
Distal gastrectomy	1.00 (reference)		
Total gastrectomy	1.65	1.27–2.13	<0.001
Surgical indication			
Malignant	1.00 (reference)		
Benign	1.36	1.07–1.73	0.013
Transfusion	2.44	1.90–3.13	<0.001
Operative time			
Operative time < median	1.00 (reference)		
Operative time ≥ median	1.19	0.94–1.52	0.15
Feeding tube	1.33	0.97–1.82	0.076
All-cause morbidity	11.6	8.85–15.2	<0.001
Multivariable			
Variable	OR	95 % CI	*p* value
Race/ethnicity			
White	1.00 (reference)		
Black or	0.53	0.33–0.85	0.008
African-American			
Hispanic	1.01	0.62–1.66	0.96
Asian, NH, PI, AI, Alaskan	0.84	0.52–1.36	0.48
Preoperative malnutrition			
Normal nutrition	1.00 (reference)		
Malnutrition	0.80	0.59–1.09	0.16
Diabetes	0.78	0.54–1.12	0.18
Smoking	1.51	1.12–2.05	0.008
Surgery type			
Distal gastrectomy	1.00 (reference)		
Total gastrectomy	1.32	0.96–1.79	0.083
Surgical Indication			
Malignant	1.00 (reference)		
Benign	0.99	0.73–1.35	0.97
Transfusion	1.30	0.96–1.76	0.088
All-cause morbidity	10.7	7.94–14.4	<0.001

C statistic 0.81

for gastric cancer between 2000 and 2012 reported a similar 4.9 % mortality rate for all patients.[29] Mortality rates following total gastrectomy have also varied from as low as zero in single-center studies to >6 % in multi-center analyses.[24, 30, 31] To address potentially modifiable risk factors in patients undergoing gastrectomy, we explored a series of clinical perioperative covariates using sequential multivariable models.

Not surprisingly, age and emergent operation (ASA class 4 and 5 patients) were associated with increased morbidity. After multivariable adjustments: tobacco use, preoperative malnutrition, total gastrectomy, benign (non-malignant) indication for resection, feeding tube insertion, and blood transfusion are all associated with an increase in postoperative morbidity. Tobacco use is a potentially modifiable risk factor and

Table 5 30-Day readmission for gastrectomy

Univariable			
Variable	OR	95 % CI	*p* value
Age	0.99	0.98–1.00	0.002
BMI	1.00	0.99–1.02	0.83
Sex			
Female	1.00 (reference)		
Male	0.93	0.76–1.13	0.44
Race/ethnicity			
White	1.00 (reference)		
Black or African-American	0.93	0.69–1.24	0.61
Hispanic	0.97	0.67–1.41	0.89
Asian, NH, PI, AI, Alaskan	1.01	0.74–1.39	0.94
Preoperative Malnutrition			
Normal nutrition	1.00 (reference)		
Malnutrition	0.88	0.69–1.11	0.29
Diabetes	1.08	0.84–1.38	0.55
Smoking	1.05	0.83–1.33	0.66
ASA Class			
ASA Class 1	1.00 (reference)		
ASA Class 2	4.15	0.56–30.7	0.16
ASA Class 3	4.43	0.60–32.6	0.14
ASA Class 4	4.63	0.62–34.7	0.14
ASA Class 5	–		
Surgery type			
Distal gastrectomy	1.00 (reference)		
Total gastrectomy	1.11	0.89–1.40	0.35
Surgical Indication			
Malignant	1.00 (reference)		
Benign	1.03	0.84–1.26	0.80
Transfusion	1.05	0.83–1.33	0.67
Operative time			
Operative time < median	1.00 (reference)		
Operative time ≥ median	1.21	0.99–1.48	0.057
Feeding tube	1.07	0.81–1.41	0.65
All-cause morbidity	2.88	2.34–3.55	<0.001
Reoperation	2.71	2.03–3.60	<0.001
Multivariable			
Variable	OR	95 % CI	*p* value
Age	0.99	0.98–0.99	<0.001
All-cause morbidity	2.65	2.11–3.33	<0.001
Reoperation	1.62	1.18–2.21	0.003

C statistic 0.64

preoperative smoking cessation has been reported to improve outcomes after gastrectomy for malignancy.[32] Malnutrition, extent of resection, and blood transfusion have been recognized as important contributors to morbidity. Blood transfusions in gastric cancer patients have also been associated with decreased recurrence-free and overall survival.[33] While indication for resection is not a modifiable risk factor, it is important to recognize that even after adjustment for significant factors including emergency operation, non-malignant diagnoses were associated with increased morbidity. Sequelae of gastric ulcer disease remain an important contributor to patient morbidity, highlighted in this patient cohort where over 35 % of gastric resections were performed for a non-malignant diagnosis. Greater than 80 % of patients with benign diagnoses had operation for peptic ulcer disease or one of its sequelae including perforation, bleeding, or stricture/obstruction.

Table 6 30-Day mortality after gastrectomy

Univariable			
Variable	OR	95 % CI	*p* value
Age	1.05	1.04–1.07	<0.001
BMI	1.00	0.98–1.02	0.86
Sex			
Female	1.00 (reference)		
Male	1.03	0.77–1.37	0.86
Race/ethnicity			
White	1.00 (reference)		
Black or African-American	0.86	0.56–1.32	0.49
Hispanic	0.39	0.18–0.83	0.015
Asian, NH, PI, AI, Alaskan	0.68	0.41–1.15	0.15
Preoperative malnutrition			
Normal nutrition	1.00 (reference)		
Malnutrition	4.54	3.37–6.12	<0.001
Diabetes	1.35	0.95–1.90	0.090
Smoking	0.86	0.60–1.23	0.41
ASA class			
ASA class 1	1.00 (reference)		
ASA class 2	0.35	0.043–2.80	0.32
ASA class 3	1.45	0.20–10.7	0.72
ASA class 4	7.92	1.07–58.8	0.043
ASA class 5	26	3.13–215.7	0.003
Surgery type			
Distal gastrectomy	1.00 (reference)		
Total gastrectomy	1.14	0.82–1.58	0.45
Surgical indication			
Malignant	1.00 (reference)		
Benign	2.03	1.51–2.71	<0.001
Transfusion	5.69	4.21–7.68	<0.001
Operative time			
Operative time < median	1.00 (reference)		
Operative time ≥ median	0.54	0.40–0.73	<0.001
Feeding tube	1.21	0.82–1.79	0.34
All-cause morbidity	13.3	9.45–18.6	<0.001
Reoperation	4.08	2.85–5.84	<0.001
Multivariable			
Variable	OR	95 % CI	*p* value
Age	1.04	1.03–1.06	<0.001
Preoperative malnutrition			
Normal nutrition	1.00 (reference)		
Malnutrition	1.86	1.31–2.65	0.001
ASA class			
ASA class 1	1.00 (reference)		
ASA class 2	0.26	0.028–2.30	0.22
ASA class 3	0.57	0.069–4.76	0.61
ASA class 4	1.24	0.15–10.5	0.85
ASA class 5	2.30	0.23–22.5	0.48
Surgical indication			
Malignant	1.00 (reference)		
Benign	1.15	0.80–1.66	0.46
Transfusion	2.00	1.40–2.87	<0.001
Operative time			
Operative time < median	1.00 (reference)		
Operative time ≥ median	0.50	0.35–0.72	<0.001
All-cause morbidity	6.78	4.62–9.95	<0.001
Reoperation	1.74	1.15–2.65	0.010

C statistic 0.90

Significantly more patients with benign diagnosis had ASA class 4/5 and required an emergent operation which likely contributed to increased morbidity and mortality in this group.

Similarly, feeding tube insertion was associated with higher morbidity. Patients who had feeding tubes were more likely to have malignancy, preoperative malnutrition, require total gastrectomy, and receive perioperative blood transfusion. While intraoperative insertion of feeding tubes was associated with greater morbidity, causation is likely multifactorial. Comparisons of surgical risk based on age and ASA class did not reveal significant differences between those patients who had feeding tubes and those who did not. However, patients who had

feeding tubes were more likely to have preoperative malnutrition, total gastrectomy, as well as malignant diagnosis. While malnutrition, extent of resection, and diagnosis are included in the multivariable morbidity model, more granular data including complications specific to feeding tubes, such as re-operation for complication of feeding tubes, tube dislodgment, tube feed intolerance, are not available. We do not believe that our study contains sufficient data to recommend either placement or avoidance of feeding tubes in this patient population.

Review of reoperation, readmission, and mortality models is important. All cause morbidity is the most significant variable associated with all three of these specific complications. Smoking is independently associated with reoperation; the association between blood transfusion and reoperation nearly reached significance ($p = 0.088$). Age, malnutrition, blood transfusion, reoperation, and all-cause morbidity are all independently associated with mortality; however, the association between NSQIP defined readmission and mortality is difficult to define.

In this study, 12.2 % of patients required readmission, which is comparable to published data.[7, 10, 14, 15] If included in the model for mortality, NSQIP defined readmission is associated with lower risk of mortality. This is likely due to two different and opposite circumstances[1]: inadequate data capture—NSQIP data collection only includes mortality for 30 days post-procedure or to the time of first discharge exclusive of discharge after readmission, or[2] hospital readmission resulted in patient care that avoided death. In an attempt to better understand this relationship, we examined institutional data for patients who had gastrectomy at our institution. Unfortunately, given relatively few cases and only two readmissions, the relationship between readmission and mortality could not be further defined. Ongoing improvements in NSQIP data collection, including further incorporation and improvement of readmission variable and further development of targeted modules, might help explain associations between readmission and mortality.

Recent expansion of minimally invasive techniques has altered approaches to surgical gastric disease at selected institutions. While choice of techniques and expertise differs, in general minimally invasive approaches are as safe or perhaps safer in selected patients.[23, 34, 35] Without a targeted NSQIP module, inclusion of minimally invasive techniques is not possible and represents a limitation of the current study. Introduction of specific minimally invasive gastric resection CPT codes or development of a targeted gastric or gastrointestinal module with improved capture of minimally invasive approach (in the absence of new CPT codes) would improve data collection and use in this patient population with higher overall mortality compared to many other major abdominal operations.

Our study demonstrates significant associations between smoking, preoperative malnutrition, blood transfusions, extent of resection, benign diagnosis, and post-gastrectomy morbidity. Post-gastrectomy morbidity is the most significant variable affecting reoperation, readmission, and mortality. Limitations in data collection, including lack of a NSQIP targeted module, restrict available analyses and interpretation of data. While institutional studies include more granular data, patient selection bias limits generalizability to broad patient population. However, certain study variables, such as readmission, are difficult to interpret given current NSQIP data collection and can be better examined using multi-institutional collaboratives. To date, recent collaboratives have focused on patients with malignancy, excluding nearly 40 % of patients requiring gastrectomy for non-malignant diagnosis. Consideration of significant postoperative morbidity and mortality in this patient population should improve process of care and patient outcomes.

Conclusions

Based on the current study, at least four potentially modifiable patient factors can be considered in limiting morbidity and mortality after gastrectomy[1]: smoking cessation and[2] preoperative nutritional optimization should be pursued[3], meticulous operative technique should limit use of perioperative blood transfusions, and[4] patients with non-malignant indications for resection and/or total gastrectomy should be considered higher risk patients with appropriately designated postoperative care pathways.

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Appendix

Malignant ICD-9 Diagnoses for Gastrectomy

145.9, 150.2, 150.5, 150.8, 150.9, 151, 151.1, 151.2, 151.3, 151.4, 151.5, 151.6, 151.8, 151.9, 152, 152.1, 152.8, 152.9, 153, 153.1, 153.2, 153.9, 154, 154.3, 155.1, 157, 157.8, 157.9, 158, 158.8, 159.1, 159.9, 162.9, 171.5, 174.8, 174.9, 183, 185, 189, 191.9, 194, 195.2, 196.2, 197.4, 197.5, 197.6, 197.7, 197.8, 198.89, 199.1, 200.2, 200.3, 200.33, 200.63, 202.8, 202.83, 209, 209.01, 209.23, 209.25, 209.29, 209.3, 209.72, 209.79, 230.2, 230.9, 235.2, 235.3, 235.5, 238, 238.1, 239, 239.2, 239.89, V10.04, V66.7

Benign ICD-9 Diagnoses for Gastrectomy

38.41, 38.9, 200.52, 209.4, 209.41, 209.6, 209.63, 209.65, 209.69, 211, 211.1, 211.2, 211.3, 211.8, 211.9, 214.3, 215.5, 228.04, 237.71, 250.6, 250.61, 250.63, 255.41, 258.01, 259.2, 263.9, 277.03, 280.9, 285.1, 285.22, 441.4, 442.83, 453, 482.82, 507, 530, 530.1, 530.11, 530.3, 530.4, 530.5, 530.81, 530.85, 530.87, 531, 531.01, 531.1, 531.11, 531.2, 531.3, 531.31, 531.4, 531.41, 531.5, 531.51, 531.6, 531.61, 531.7, 531.71, 531.9, 531.91, 532, 532.01, 532.1, 532.11, 532.2, 532.31, 532.4, 532.41, 532.5, 532.51, 532.6, 532.7, 532.71, 532.9, 532.91, 533, 533.1, 533.4, 533.41, 533.5, 533.51, 533.6, 533.7, 533.71, 533.9, 533.91, 534, 534.01, 534.2, 534.3, 534.4, 534.41, 534.5, 534.6, 534.7, 534.71, 534.9, 534.91, 535, 535.01, 535.1, 535.11, 535.2, 535.4, 535.41, 535.5, 535.61, 536.1, 536.3, 536.41, 536.8, 536.9, 537, 537.1, 537.3, 537.4, 537.6, 537.8, 537.82, 537.83, 537.84, 537.89, 537.9, 551.3, 552.2, 552.3, 552.8, 553.21, 553.3, 553.9, 555, 557, 557.1, 557.9, 560.2, 560.31, 560.8, 560.81, 560.89, 560.9, 562, 562.02, 562.1, 564.2, 564.3, 564.89, 567.21, 567.22, 567.29, 567.38, 567.89, 567.9, 568, 568.81, 568.89, 569.69, 569.81, 569.83, 569.89, 572.3, 574.1, 575, 575.12, 576.2, 576.8, 577.1, 577.2, 577.8, 577.9, 578, 578.9, 584.9, 648.93, 682.2, 717.83, 750.7, 751.5, 751.7, 758.9, 786.09, 787, 787.02, 787.2, 789, 789.07, 789.3, 793.89, 799.89, 879.2, 935.2, 936, 995.92, 996.59, 996.69, 997.4, 997.49, 998.09, 998.11, 998.2, 998.3, 998.59, 998.6, 998.89, E878.2, V12.71, V16.0, V50.49, V83.89

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