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Research Paper

Laparoscopic compared to open approach for distal gastrectomy may reduce pneumonia risk for patients with gastric cancer☆

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ABSTRACT

Background: Whether laparoscopic approach to gastrectomy for gastric cancer (GC) reduces the risk of pneumonia remains unknown. In this study, we compared pneumonia outcomes for patients with GC who underwent either laparoscopic gastrectomy (LG) or open gastrectomy (OG).
Methods: The ACS NSQIP database was queried to identify patients with GC who underwent LG or OG between Jan 2012 - Dec 2018. Outcomes were compared using regression models. A post-hoc analysis was performed for elderly patients.
Results: The study cohort included 2661 patients, 23.4 % undergoing LG. Laparoscopic approach lowered pneumonia risk (OR 0.47, $p = .028$) and reduced hospital length of stay, (5.3 vs 7.1 days, $p < .001$). Elderly patients undergoing LG demonstrated similar benefits. Risk factors for pneumonia included advanced age, dyspnea and weight-loss, whereas laparoscopic approach reduced this risk.
Conclusions: LG in patients with GC has both statistically and clinically significant advantages over OG with respect to pneumonia. Further studies are needed to validate the relationship between postoperative pneumonia and surgical approach for gastrectomy.

Introduction

Approximately 26,000 people in the United States are diagnosed with gastric adenocarcinoma (GC) annually, with an estimated 11,000 deaths per year [1]. Multimodality therapy involving complete surgical resection with lymphadenectomy is the only curative approach for early-stage disease [2,3]. When selecting a surgical approach for gastrectomy, surgeons must weigh oncologic, individual patient factors, the surgeon's individual experience and local practice guidelines.

Open gastrectomy (OG) is the historical gold standard approach for GC, yet portends significant morbidity for patients [4]. In recent decades, laparoscopic gastrectomy (LG) has rapidly evolved as an alternative surgical approach. LG was first described by Kitano in 1994 [5]. Since then, multiple randomized controlled trials (RCTs) have demonstrated equivalent or improved outcomes compared to OG, including lower complication rates, equivalent lymph node harvest and equivalent overall survival (OS) [6–8]. A follow-up of the CLASS-1 trial recently demonstrated no difference in five-year OS between LG vs OG [9]. Additional benefits of LG, including shorter hospital length of stay (HLOS) and fewer major complications have also been described [10,11].

Postoperative pneumonia remains one of the most common and fatal complications among GC patients [12–15]. Previous reports have shown pneumonia was responsible for 18 % of deaths caused by diseases other than GC following gastrectomy [16]. This association is understood to be related to lower respiratory function and dysfunctional swallowing that progresses with age [17]. The use of a laparoscopic approach for other abdominal surgeries has shown a potential benefit in reducing the rate of postoperative pneumonia [18–20]; however, this effect has not been well established in GC patients undergoing gastrectomy.

Therefore, our primary aim was to provide an updated comparison of short-term pneumonia outcomes for patients with GC who underwent

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either LG or OG. Our secondary, exploratory aim was to evaluate these outcomes in elderly patients as advanced age is associated with higher risks of pneumonia [21]. We hypothesized LG would demonstrate lower 30-day rates of respiratory-related outcomes compared to OG. Primary outcome was pneumonia within 30-days, and secondary outcomes included reintubation, failure to wean from ventilator, discharge to facility, and hospital length of stay (HLOS). We utilized the American College of Surgeon's National Surgical Quality Improvement Program (ACS NSQIP) database to address this hypothesis.

Materials and methods

Data Source

We utilized the 2012–2018 ACS NSQIP Participant Use Files to create the patient database. Approval to conduct this study was obtained from the ACS NSQIP. Raw NSQIP .sav files were converted to Microsoft Excel and merged into a single spreadsheet. Variables were then manually aligned, as they varied annually, to reflect column headings.

Cohort selection

We identified patients over the age of 18 who were diagnosed with gastric adenocarcinoma using the International Classification of Diseases (ICD) codes for malignant neoplasm of the stomach (ICD-9:151.0-151.9, ICD-10: C16.0-16.9). From this initial cohort, patients who underwent surgical resection were identified by Current Procedural Terminology (CPT) codes for subtotal / distal open gastrectomy (43631-43634) and laparoscopic gastrectomy (43659,43644-5, 43845-6, 43775). Total gastrectomy cases were excluded as previously described [22]. To generate a cohort that better represented the average patient with GC who underwent elective gastrectomy with oncologic intent, we excluded patients with emergency operations, American Society of Anesthesiologists (ASA) classification 4 or 5, preoperative wound infection, preoperative sepsis, outpatient operation, previous operation within 30 days, disseminated cancer, and NSQIP outcomes present at time of surgery (PATOS).

Description of covariates

'Variable label' provided by the NSQIP database was utilized to represent each covariate, abbreviated as applicable, in accordance with the ACS NSQIP User Guide. The covariate BMI, if not listed, was calculated as patient weight (kg) divided by height (m) [2]. Race and ethnicity covariates were merged for Hispanic / White, non-Hispanic / White and White / ethnicity unknown. The remaining race covariates were not merged with ethnicity given high 'ethnicity unknown' frequencies among these groups. Diabetes 'insulin' and 'non-insulin' entries were combined to allow for bivariate analysis.

Outcome measurements

Outcome frequencies among the two groups were extracted from the NSQIP database. Outcome labels were amended using the ACS NSQIP Data User Guide. Mortality within 30 days was calculated using the "DOpertoD" variable, assigning patient mortality for values other than −99. The outcome 'any SSI' was created by combining the following wound complication variables: "SUPINFEC", "WNDINFD", "ORGSPCSSI". The outcome 'discharge to facility' was created by combining responses from "DISCHDEST" including 1) skilled care, not home, 2) unskilled facility, not home, 3) facility which was home, 4) separate acute care, 5) hospice and 6) rehab to allow for bivariate analysis. All outcomes within NSQIP are precisely defined using criteria for each condition measured. Pneumonia, for example, is defined by both radiographic and clinical parameters [23].

Balancing patient covariates

To address the potential for a large number of confounders among the study cohort, the inverse probability of treatment weighted (IPTW) method was utilized to balance patient covariates. The propensity score (PS) model included all baseline variables [24]. Quality of the PS model was assessed by evaluating covariate balance between treatment groups in weighted samples using box and whisker plots.

Non-normally distributed variables were log transformed for the purpose of the analysis and were summarized in terms of geometric means and geometric standard deviations, as appropriate. Missing data for the covariates were imputed using the method of chained equations. Covariates were compared between groups using weighted samples by the Fisher Exact or Chi Squared test in the case of categorical variables or the Wilcoxon or Kruskal-Wallis test in the case of continuous variables to verify that the PS method was successful in balancing the covariates. Binary outcomes were compared between groups using IPTW logistic model whereas continuous outcomes were compared on the log scale using IPTW linear regression model and reported as geometric means and geometric standard deviations.

Univariable and multivariable logistic regression models were performed to determine independent associations between baseline patient characteristics and operative approach to the study outcomes. Continuous covariates were converted to categorical data based on clinically relevant cutoffs, these included age and BMI in order to perform logistic regression analyses. Outcome measurements were presented as odds ratios (OR). Candidate covariates were based on clinical relevancy, and final models were selected using backwards or forwards variable selection based on the Akaike Information Criterion (AIC) [25]. Goodness of fit for the regression models was assessed using the concordance (C) statistic and the Hosmer-Lemeshow (H-L) test. Multiple testing adjustments were performed using the False Discovery Rate (FDR) method.

Post hoc subgroup analysis

To address our exploratory aim whether elderly patients specifically would benefit from laparoscopic approach, a post-hoc subgroup analysis was performed. The term 'elderly' was defined as age $\geq$ 70 years based on prior literature [26]. Outcome measurements were then performed similarly, data presented as OR. Due to small sample size, multivariable regression analysis was not possible in this cohort.

Statistical analysis

All analyses were performed using SAS 9.4 (Copyright (c) 2002–2012 by SAS Institute Inc., Cary, NC, USA.). Statistical significance was defined as $p < .05$ with 95 % confidence intervals (95 % CI).

Results

Baseline characteristics of study cohort

Between 2012 and 2018, there were 10,346 patients included in the NSQIP database that were diagnosed with GC. Of these cases, 3806 (37 %) underwent surgical resection. After applying the exclusion criteria, 2661 patients were included in the final cohort, including 624 (23 %) patients who underwent LG and the remaining 2037 (77 %) undergoing OG (Fig. 1).

Baseline patient characteristics from the study cohort are summarized in Tables 1 and 2. The groups appeared to be well balanced, as there were no significant differences between baseline patient characteristics. Comparison of the propensity scores by intervention also demonstrated elimination of non-overlap, suggesting appropriate modeling (Fig. 2). The study cohort included mostly older adults, with a mean age of 66 years. The majority of patients had underlying hypertension and were categorized as ASA classification 3. Prior to balancing

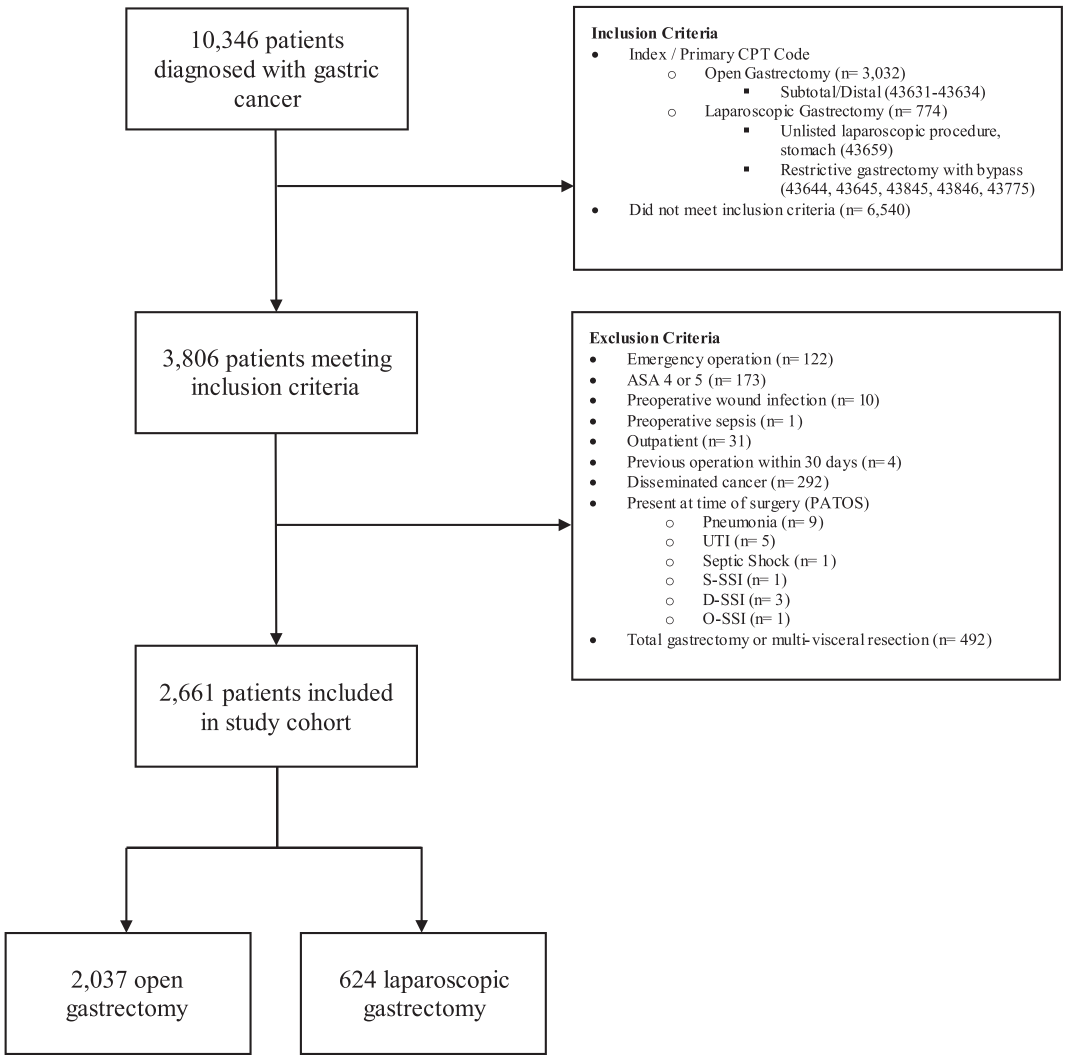

Fig. 1. Flow diagram of the study cohort selection process.

Table 1
Study Cohort weighted continuous covariates.

	Laparoscopic	Open	*p* Value
Age (years)	66.0 (14)	66.2 (13)	.73
BMI (kg/m^2)	26.9 (6.6)	27.1 (5.9)	.37
Preoperative lab values			
Sodium	140 (3.0)	140 (3.0)	.99
BUN[a]	14.7 (1.5)	14.7 (1.6)	.91
Creatinine[a]	0.90 (1.4)	0.90 (1.4)	.43
Albumin	3.8 (0.7)	3.9 (0.6)	.60
Total Bilirubin[a]	0.40 (1.8)	0.40 (1.7)	.90
AST[a]	22 (1.6)	22 (1.6)	.83
ALP[a]	74 (1.5)	74 (1.5)	.57
WBC[a]	6.2 (1.4)	6.3 (1.4)	.66
Hematocrit	37 (6.1)	37 (5.4)	.68
Platelets[a]	224 (1.4)	226 (1.4)	.80

Data presented as mean (standard deviation) unless otherwise indicated. ALP, alkaline phosphatase; AST, aspartate transaminase; BMI, body mass index; BUN, Blood urea nitrogen; WBC, white blood cell count.
p values calculated by inverse probability weighting analysis.
[a] Values listed as geometric mean (geometric standard deviation).

baseline covariates, white / ethnicity unknown, Native Hawaiian or Pacific Islander and white / non-Hispanic demonstrated the highest frequencies of LG (Supplemental Fig. 1).

Risk-adjusted outcomes by operative approach

Within the study cohort, LG was associated with a lower risk of pneumonia when compared to OG, OR 0.47 (0.26, 0.84) $p = .028$. Reintubation, failure to wean from a ventilator and discharge to facility were not different between the two groups. HLOS was noted to be lower among patients receiving LG, 5.3 vs 7.1 days, $p \leq .001$. Exploratory outcomes noted an associated lower risk of both any complication and readmission (Table 3 and Supplemental Table 1).

Risk-adjusted associations for pneumonia

To further explore the benefits of LG, we performed a multivariable regression analysis for pneumonia (Table 4). Laparoscopic approach, any dyspnea, history of COPD, transfusion given, history of diabetes mellitus, steroid use, weight loss, age, BMI, gender and smoking history were included within the full model. Covariates within the final model included laparoscopic approach, any dyspnea, weight loss, age 70+, BMI > 30, BMI < 18.5 and smoking history. Laparoscopic approach was the only covariate associated with a lower risk of pneumonia, OR 0.44 (0.22, 0.85) $p = .015$. Age 70+, any dyspnea and weight loss were associated with a higher risk of pneumonia, OR 1.6 (1.1, 2.5) $p = .031$, OR 2.28 (1.3, 4.1) $p = .007$ and OR 1.9 (1.1, 3.5) $p = .031$, respectively.

Table 2
Study Cohort weighted categorial covariates.

	Laparoscopic	Open	*p* value
Demographics			
Surgery Year			.95
2012	97 (25.7)	280 (74.3)	–
2013	103 (25.4)	303 (74.6)	–
2014	113 (25.9)	324 (74.1)	–
2015	81 (26.6)	223 (73.4)	–
2016	123 (26.1)	349 (73.9)	–
2017	123 (28.7)	306 (71.3)	–
2018	99 (26.3)	278 (73.7)	–
Sex – Female	329 (44)	908 (44)	.83
American Indian or Alaska Native	2 (13)	11 (86.5)	.94
Asian	146 (26.7)	402 (73.3)	–
Black or African American	109 (25.4)	319 (74.6)	–
Native Hawaiian or Pacific Islander	4 (21.2)	14 (78.8)	–
Unknown/Not Reported	121 (28.1)	310 (71.9)	–
White (ethnicity unknown)	7 (24.7)	20 (75.3)	–
White, Hispanic	63 (25.6)	184 (74.4)	–
White, Non-Hispanic	289 (26.4)	803 (73.6)	–
Patient comorbidities			
Smoking Hisory	122 (17)	351 (17)	.75
Any Dyspnea	48 (6.4)	137 (6.7)	.83
Partially Dependent Functional Status	14 (1.9)	43 (2.1)	.98
Diabetes Mellitus	154 (21)	448 (22)	.62
Ascites	0 (0.0)	3 (0.1)	.33
COPD	32 (4.3)	88 (4.3)	.99
CHF	3 (0.5)	14 (0.7)	.53
Renal Failure	1 (0.2)	3 (0.2)	.73
Dialysis	3 (0.5)	7 (0.3)	.60
Weight loss	62 (8.4)	168 (8.1)	.82
Steroid use	25 (3.4)	69 (3.4)	.96
Hypertension	404 (55)	1135 (55)	.85
Bleeding Disorder	18 (2.5)	50 (2.4)	.96
Blood transfusion	21 (2.9)	50 (2.4)	.52
Chemotherapy	2 (0.3)	8 (0.4)	.89
Radiation therapy	1 (0.1)	3 (0.2)	.89
ASA Class 3	508 (69)	1424 (69)	.84

Data presented as patient count (% of patients within individual groups). CHF, congestive heart failure;
COPD, chronic obstructive pulmonary disease; ASA, American Society of Anesthesiologists. Partially dependent is a measurement of functional status. *p* values calculated by inverse probability weighting analysis.

Post hoc subset outcome analysis for elderly patients

Elderly patients underwent LG less often compared to younger adults (22.8 % vs 30.0 %, $p = .024$) and experienced higher rates of any complication (32.8 % vs 48.5 %, $p < .001$). Within our exploratory model, LG compared to OG was associated with a lower risk of pneumonia, OR 0.45 (0.21, 0.98) $p = .044$ (Table 5 and Supplemental Table 2). LG was also associated with a lower risk of discharge to a skilled nursing facility, OR 0.63 (0.44, 0.91), $p = .015$ and a reduced

Table 3
30-day postoperative outcomes following gastrectomy for patients with gastric adenocarcinoma, by operative approach.

Outcome	OR	*p* value	Adjusted *P* Value	n (%)
Pneumonia	0.47 (0.26, 0.84)	.01*	.028*	92 (3.4)
Reintubation	0.98 (0.49, 1.96)	.95	.95	41 (1.5)
Failure to Wean from Ventilator	1.56 (0.79, 3.10)	.20	.25	36 (1.3)
Discharge to Facility	0.75 (0.55, 1.02)	.07	.12	259 (10.2)
Total Hospital Length of Stay (days)[a]	LAP 5.3 (2.0) / OPEN 7.1 (1.7)	<.001*	<.001*	–
Exploratory outcomes				
Any Complication	0.75 (0.62, 0.91)	.00*	.03*	784 (38.8)
Death	1.04 (0.51, 2.11)	.92	.95	39 (1.4)
Any SSI	0.65 (0.45, 0.94)	.02*	.12	188 (7.2)
Pulmonary Embolism	0.79 (0.27, 2.29)	.66	.82	20 (0.70)
Transfusion Given	0.93 (0.70, 1.25)	.64	.82	259 (10.2)
Sepsis	0.91 (0.57, 1.50)	.75	.87	87 (3.1)
Septic Shock	0.26 (0.08, 0.87)	.03*	.13	32 (1.2)
Readmission	0.58 (0.42, 0.80)	.00*	.01*	265 (12.0)

Lap, laparoscopic; SSI, surgical site infection. Data presented as odds ratio laparoscopic vs open (95 % confidence interval). Frequency of outcome from the study cohort is listed as n (%). *P* values were adjusted using false discovery rate (FDR).
[*] *p* value < .05.
[a] Continuous data, listed as geometric mean (geometric SD).

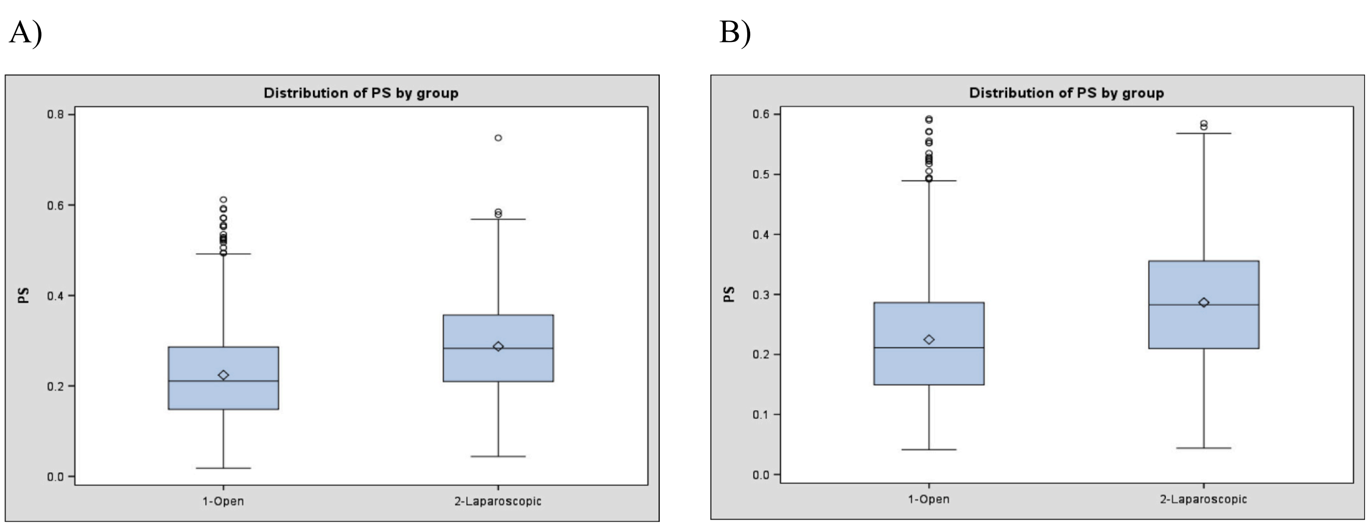

Fig. 2. Comparisons of propensity scores by intervention cohorts.
Box and Whisker Plot Comparison of Propensity Scores by Intervention. A) Evaluating common support by comparing distributions of the PS. B) Elimination of regions of non-overlap in the propensity score. Missing values for continuous variables were imputed for the purpose of estimating propensity scores (PS).

Table 4
Multivariable logistic regression model demonstrating risk-adjusted associations for pneumonia.

	Full Model		Final Model	
Covariate	OR (95 % CI)	p value	OR (95 % CI)	p value
Laparoscopic Approach	0.42 (0.22, 0.83)	.015*	0.44 (0.22, 0.85)	.015*
Any Dyspnea	2.16 (1.2, 4.1)	.016*	2.28 (1.3, 4.1)	.007*
COPD	0.98 (0.39, 2.4)	.96	–	–
Transfusion given	0.96 (0.29, 3.2)	.95	–	–
Diabetes Mellitus	0.97 (0.59, 1.6)	.91	–	–
Steroid Use	1.1 (0.32, 3.5)	.93	–	–
Weight Loss	1.9 (1.0, 3.6)	.038*	1.9 (1.1, 3.5)	.031*
Age 70+	1.7 (1.1, 2.6)	.026*	1.6 (1.1, 2.5)	.031*
BMI > 30.0	1.4 (0.88, 2.3)	.15	–	–
BMI < 18.5	1.8 (0.70, 4.5)	.23	–	–
Sex – Male	1.1 (0.73, 1.7)	.58	–	–
Smoking History	1.6 (0.92, 2.7)	.097	1.6 (0.92, 2.6)	.10

Candidate covariates were chosen based on clinical relevancy. Final model was selected based on AIC criterion. Data presented as odds ratio and (95 % confidence interval). Final C statistic 0.671, H-L Test: Chi-square 4.49, DF 6, $p = .61$. Reference groups: Open approach, No dyspnea, No COPD, No transfusions given, No Diabetes, No steroids, No weight loss, Age < 70 years, BMI 18.5–30, Sex - Female.

* p value < .05.

Table 5
Post hoc 30-day post-operative outcome analysis for elderly patients undergoing gastrectomy for gastric adenocarcinoma.

	Age 70+		
Outcome	OR		p value
Pneumonia	0.45 (0.21, 0.98)		.044*
Reintubation	0.80 (0.33, 1.97)		.63
Failure to Wean from Ventilator	1.41 (0.54, 3.68)		.48
Discharge to Facility	0.63 (0.44, 0.91)		.015*
Any Complication	0.67 (0.51, 0.89)		.005*
Death	1.36 (0.64, 2.9)		.43
Any SSI	0.50 (0.27, 0.92)		.026*
Transfusion Given	0.73 (0.49, 1.1)		.14
Sepsis	0.66 (0.31, 1.4)		.29
Septic Shock	0.29 (0.07, 1.1)		.075
Readmission	0.68 (0.44, 1.05)		.082
	LAP	OPEN	
Total Hospital Length of Stay (days)[a]	5.26 (2.1)	7.64 (1.7)	<.001*

Table 5: Subset outcome analysis of elderly patients undergoing laparoscopic or open gastrectomy, data listed as odds ratio (laparoscopic / open), p value calculated by inverse probability weighted analysis. FDR adjustments were not performed, as this analysis was exploratory.

* p value < .05.

[a] Continuous data, listed as geometric mean (geometric standard deviation).

HLOS, 5.26 vs 7.64 days, $p < .001$. Odds of any complication and any SSI were also lower in the LG cohort.

Discussion

In the present study, we show that LG is associated with a lower pneumonia risk and HLOS compared to OG. Within our post hoc analysis, LG was also associated with a lower risk of pneumonia and discharge to a facility for elderly patients. Laparoscopic approach was shown to associate with a lower risk of pneumonia in our multivariable models, whereas any dyspnea or weight loss increased this risk. These important findings represent an additional potential benefit of LG over OG that should be considered when selecting an operative approach for the treatment of distal GC.

The mechanism underlying reduced pneumonia rates following LG remains largely unknown. However, laparoscopic abdominal surgery is considered to cause less pulmonary complications due, in part, to reduced incisional pain and diaphragmatic dysfunction. While many studies have compared the pulmonary effects of open and laparoscopic surgery in a variety of procedures [18–20], few studies have evaluated these effects in gastrectomy [27]. For example, Osman et al. showed that all immediate postoperative pulmonary function test (PFT) values were lower in patients who underwent an open approach to cholecystectomy compared to the laparoscopic approach [28]. This pulmonary deficit was observed to normalize by the sixth postoperative day. Some studies have advocated that laparoscopy better preserves the immune system to lessen the proinflammatory cytokine response related to surgery [29–31], though definitive conclusions cannot be made. Preoperative presentation including gastric outlet obstruction, bleeding and/or cancer cachexia may predispose patients to higher risk of aspiration. Also, postoperative HLOS increases the risk of developing pneumonia, particularly in the elderly [32,33]. We observed shorter HLOS in LG compared to OG patients by an average of 2 days. As such, the lower risk for developing pneumonia observed in LG may also be attributed to shorter hospitalization.

Elderly patients have experienced an increased incidence of GC worldwide [34]. While recent evidence has suggested multiple benefits in laparoscopic gastrectomy (LG) over open gastrectomy (OG), elderly patients were often a minority or excluded altogether [6,9,35,36]. Current guidelines lack recommendations on the optimal surgical approach for elderly patients with GC. Management of GC in the elderly presents several challenges including lower physiologic reserve, depressed immune system, higher rates of malnutrition, presence of multiple comorbidities, and decreased willingness to pursue oncologic treatment [37,38]. Surgical planning for elderly patients must appreciate the higher rates of mortality, postoperative complications and prolonged HLOS in this population [39,40].

Prior studies have shown LG can be safely performed in the elderly; however, these patients are prone to the development of malnutrition and pneumonia [41,42]. Weight loss after gastrectomy is also a serious concern, as prior studies have shown lower quality of life and long-term prognosis associated with this outcome [43]. Our current study demonstrated a lower risk of overall complications, pneumonia, HLOS and discharge to a facility in elderly patients who undergo LG compared to OG – benefits that may reduce morbidity and mortality beyond the 30-day follow-up period. Some centers utilize multi-disciplinary programs to reduce postoperative pneumonia rates in the elderly [17,44,45]. Such efforts should be considered and adapted by various centers for inclusion into future perioperative optimization and enhanced recovery after surgery (ERAS) programs [46]. Early postoperative supplemental feeding, either enteral or parenteral, is one of the most important aspects of these programs, having been previously shown to improve nutrition and reduce HLOS [47].

Our study did demonstrate disparities of LG among various race and ethnicities (Supplemental Fig. 1). While the NSQIP database does not differentiate between hospital demographics, previous studies have shown socioeconomic differences in the utilization of LG could be explained by hospital level factors [48].

There are several limitations from this study we wish to highlight. This study was retrospective in nature and therefore prone to selection bias due to unmeasured confounders. Given the anonymity of the database, we were unable to assess individual surgeon's experience levels or determine conversion rates from LG to OG. Previous studies have shown higher rates of conversion from laparoscopic to open procedures among elderly patients [49]. We acknowledge the potential for miscoded data, including incorrect diagnoses and operation performed. Robotic-assisted procedures were also not captured within the current database. Additional variables including cancer staging, neoadjuvant chemoradiation, lymph node yield, surgical margins, and oncologic intent of surgery were not captured within this database. The frequency of several outcomes were low, making it difficult to provide definitive conclusions. We are also limited to 30-day outcomes following gastrectomy as collected within the NSQIP database. Rates of anastomotic leaks were not captured, and represent a clinically important complication of gastrectomy. Future studies would benefit from a procedure targeted participant use data file (PUF) for gastrectomy to enhance ongoing research, similar to that of colectomy and pancreatectomy, which are currently provided by NSQIP.

Despite the benefits of LG over OG for the treatment of GC, the surgical community has been slow to utilize this approach. In our current study, 77 % of patients underwent OG and the mean age was 66 years. Further prospective and randomized studies assessing the feasibility and associated benefits of LG, including among the elderly, are warranted. A phase II RCT by Li et al. enrolling patients age 70 and above is currently being performed [50], which may catalyze adoption of LG in this age group. Future trials are recommended to also include patient-directed outcomes such as pain scales, patient satisfaction, caregiver burden assessment, quality of life years and return to work metrics. In the advent of robotic surgery, we will also likely see increased utilization of robotic gastrectomy (RG). RG may be faster to adapt, as it is associated with shorter learning curves compared to LR [51,52]. Additionally, a recent single center RCT comparing LG vs RG demonstrated lower morbidity, faster recovery and improved lymphadenectomy with RG [53]. As surgical technology advances towards more advanced minimal invasive approaches, so should its utilization.

Conclusion

LG in patients with GC has both statistically and clinically significant advantages over OG with respect to postoperative pneumonia. These advantages were also apparent among the elderly, suggesting LG as the preferred approach for this population. However, further studies are needed to fully establish the relationship between surgical approach and postoperative pneumonia.

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Credit authorship contribution statement

BK, MG and KK designed the project; MG, BK and VC provided supervision; KK organized clinically annotated patient databases, DM performed all statistical analyses, KK created all figures, KK wrote the manuscript, with critical review from all authors.

Ethics approval

The ACS NSQIP database includes de-identified patient information, such that this was exempt from ethics approval.

Declaration of competing interest

All authors disclose that the American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors. All authors declare no related conflicts of interest to declare.

Data availability

The authors declare all data necessary to evaluate the conclusions of this study are available within the manuscript and provided supplemental materials.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sopen.2023.07.006.

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