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Outcomes of robotic versus non-robotic minimally-invasive esophagectomy for esophageal cancer: An American College of Surgeons NSQIP database analysis

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ABSTRACT

Background: Utilization of robotic-assistance for esophagectomy is increasing. The differences in outcomes between robotic-assisted minimally-invasive esophagectomy (RAMIE) and non-robotic minimally-invasive esophagectomy (MIE) for esophageal cancer are unknown. The purpose of this study was to compare 30-day postoperative outcomes between RAMIE and MIE.

Methods: A retrospective analysis was conducted using the ACS-NSQIP 2016–2017 databases. Primary outcome was 30-day postoperative mortality and morbidity.

Results: 725 minimally-invasive cases were identified, which included 100 RAMIE and 625 MIE. RAMIE was not found to be a risk factor for postoperative mortality (OR 1.50, 95% CI 0.38–6.00, $p = 0.5675$) or overall morbidity (OR 0.65, 95% CI 0.40–1.06, $p = 0.0818$). No significant differences were found between groups for systemic, organ-specific, or surgical complications.

Conclusions: No significant difference was found in the incidence of 30-day postoperative outcomes between RAMIE and MIE. In comparison to MIE, RAMIE may be considered a feasible but non-superior option for treatment of esophageal cancer.

Introduction

Esophageal cancer is the sixth leading cause of cancer-related mortality worldwide, and esophagectomy remains the main method for surgical treatment of locally advanced cancer.[1,2] Minimally-invasive esophagectomy (MIE) via a combination of thoracoscopic and laparoscopic approaches was initially adopted due to the high morbidity associated with open esophagectomy (OE).[3,4] Several retrospective and one randomized control trial have compared outcomes of MIE to OE and have shown either superior or non-inferior rates of short-term perioperative morbidity and mortality with MIE.[4–11]

Recently, the utilization of robotic-assisted minimally-invasive esophagectomy (RAMIE) has steadily increased as robotic-assisted surgical systems have become more available.[10] The first robotic-assisted minimally-invasive esophagectomy (RAMIE) was performed in 2002. Since then studies comparing RAMIE to MIE have primarily been limited to small cohort comparisons at single institutions.[13–17] Larger, retrospective studies of the National Cancer Database have compared RAMIE to MIE but this database lacks comprehensive data on systemic and organ-specific postoperative complications.[3,6,9] Possible advantages of RAMIE over MIE include increased operative precision and maneuverability within the confined space of the mediastinum and improved postoperative recovery and complication rates.[3,15,16] Conversely, any benefits of RAMIE may be overshadowed by potentially longer operating times and the significant financial costs associated with robotic surgery.[13,16–18]

The purpose of this study was to compare 30-day postoperative outcomes between RAMIE and MIE. We hypothesized that there is no difference in postoperative outcomes between the two approaches.

Materials and methods

Data source

The American College of Surgeons National Surgical Quality

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Improvement Program (ACS-NSQIP) is a nationally-validated database of risk-adjusted surgical outcomes designed to measure and improve the quality of surgical care. The ACS-NSQIP Participant Use Files (PUF) are comprised of over 150 variables in several categories, including demographics, preoperative data, and 30-day postoperative outcomes. First released in 2016, the ACS-NSQIP Esophagectomy-Targeted Participant Use File (PUF) contains esophagectomy-specific data from over 70 participating hospitals.

Cohort selection and comparison groups

A retrospective study was conducted using the ACS-NSQIP general PUF and Esophagectomy Targeted PUF from 2016 to 2017 to investigate outcomes of patients who underwent RAMIE or MIE for esophageal cancer. Minimally-invasive esophagectomy cases were identified from the Esophagectomy Targeted PUF based on surgical approach and minimally-invasive approach data points. Cohort selection criteria are summarized in Fig. 1.

Surgical approach was classified as either non-robotic minimally-invasive esophagectomy (MIE) or robotic-assisted minimally invasive esophagectomy (RAMIE). A case was identified as minimally-invasive if it was documented that the resection was performed by robotic assistance, laparoscopy, thoracoscopy, or other minimally-invasive surgery. Cases utilizing a hybrid surgical approach were also included if it was documented that the approach was entirely minimally-invasive. Cases utilizing a non-minimally-invasive hybrid surgical approach and cases with planned open conversion were excluded from analysis. Minimally-invasive surgical approach was defined based on intention to treat, thus, any case that started as a minimally invasive approach but required unplanned conversion to open was included as a minimally-invasive surgery.

Patient population

Patient demographics, preoperative comorbidities, and clinical measurements were analyzed between groups. Demographic variables included age, sex, body mass index (BMI), and race.

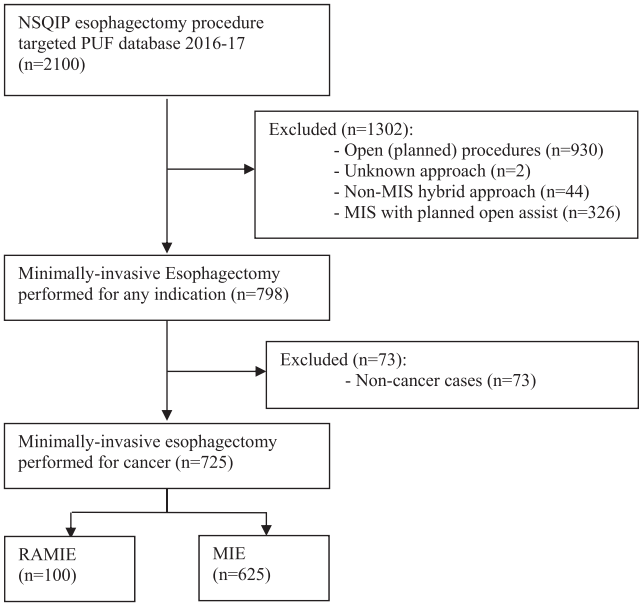

Fig. 1. Flow chart of cohort selection for analysis. Abbreviations: minimally invasive surgery (MIS); robotic-assisted minimally-invasive esophagectomy (RAMIE); minimally-invasive esophagectomy (MIE).

Preoperative comorbidities were categorized by the presence or absence of specific conditions or risk factors and included congestive heart failure, hypertension requiring treatment, cigarette smoking within 1 year, dyspnea within 30 days, chronic obstructive pulmonary disease, ventilator requirement within previous 48 h, pneumonia, dialysis, weight loss >10% in last 6 months, disseminated cancer, chemotherapy within 90 days, radiation therapy within 90 days, bleeding disorder, preoperative transfusion within 72 h before surgery, open or infected wound, sepsis or septic shock, diabetes mellitus, and steroid or immunosuppressant therapy within 30 days. Preoperative clinical measurements included functional status, American Society of Anesthesiologists (ASA) class, and select clinical laboratory data (albumin, bilirubin, creatinine, hematocrit, international normalized ratio, platelet count, and white blood cell count). Esophageal cancer clinical and pathologic TNM staging (American Joint Committee on Cancer 7th Edition) was compared between groups.[19] Patients with incomplete staging data were excluded from this analysis.

Outcomes

The principal outcomes of this study were the 30-day postoperative mortality and overall morbidity rates. Overall morbidity was determined by presence of at least one major postoperative complication: stroke, cardiac arrest, myocardial infarction, pneumonia, failure to wean from ventilator within 48 h, reintubation, renal failure, renal insufficiency, deep venous thrombosis, pulmonary embolism, surgical site infection, wound dehiscence, sepsis, septic shock, bleeding requiring transfusion, or anastomotic leak. Major complications were also classified into groups and included cardiac, pulmonary, renal, venous thromboembolism, wound, and sepsis/septic shock. Secondary outcomes included rates of positive resection margins, unplanned conversion to open surgical approach, readmission, and unplanned reoperation as well as discharge destination and length of postoperative hospital stay. Comparison of resected lymph node counts between RAMIE and MIE was not able to be performed as this variable is not reported in the NSQIP database.

Statistical analysis

Univariate analysis of preoperative and postoperative variables was conducted using the Chi-squared test for categorical variables and the Mann Whitney *U* test for continuous variables. Multivariate analysis of postoperative outcomes was conducted using a logistic regression model that included demographics and preoperative variables that were different between the RAMIE and MIE groups at a univariate *p*-value of <0.25. A risk adjusted odds ratio and corresponding 95% confidence interval for patients undergoing RAMIE for each morbidity variable was calculated. Statistical significance was assigned to *p*-values <0.05. Statistical analysis was performed using SAS version 9.4.

Results

Preoperative demographic, comorbidity, and clinical staging data are summarized in Table 1. The mean age of all patients was 64 years, and the majority of patients were men (84.14%). Adenocarcinoma was the predominant type of cancer (72.69%). On univariate analysis of demographic variables, no significant age, BMI, or gender differences were observed between groups but patients undergoing RAMIE were more likely to be white (92.0% versus 76.5%, $p = 0.0004$). Univariate analysis of preoperative comorbidities and risk factors showed higher rates of dyspnea within 30 days of surgery (18.00% versus 8.16%, $p = 0.0124$) and non-independent

Table 1
Patient demographics and preoperative variables for RAMIE and MIE. *p < 0.05.

Pre-Operative Variable	All	MIE	RAMIE	p-value
n (% of total)	725 (100%)	625 (86.21%)	100 (13.79%)	
Age, y, mean ± SD	64 ± 9.35	64 ± 9.35	64 ± 9.40	0.6877
Age ≥ 65, n (% of group)	379 (52.28%)	331 (52.960%)	48 (48.00%)	0.3565
Gender male, n (% of group)	610 (84.14%)	528 (84.48%)	82 (82.00%)	0.5285
Race white, n (% of group)	570 (78.62%)	478 (76.48%)	92 (92.00%)	0.0004*
BMI, kg/m2, mean ± SD	27.7 ± 5.78	27.6 ± 5.84	27.8 ± 5.45	0.8164
Obese (BMI ≥ 30 kg/m2), n (% of group)	217 (29.93%)	183 (29.28%)	34 (34.00%)	0.3386
Functional status not independent, n (% of group)	7 (0.97%)	4 (0.64%)	3 (3.00%)	0.0250*
ASA classification I-II, n (% of group)	126 (17.38%)	114 (18.24%)	12 (12.00%)	0.1246
ASA classification III, n (% of group)	563 (77.66%)	483 (77.28%)	80 (80.00%)	
ASA classification IV-V, n (% of group)	36 (4.97%)	28 (4.48%)	8 (8.00%)	
Emergency case, n (% of group)	1 (0.14%)	1 (0.16%)	0 (0.00%)	0.6890
Congestive heart failure, n (% of group)	1 (0.14%)	0 (0.00%)	1 (1.00%)	0.1379
Hypertension requiring treatment, n (% of group)	344 (47.45%)	299 (47.84%)	45 (45.00%)	0.5975
Smoke cigarettes within 1 year, n (% of group)	176 (24.28%)	148 (23.68%)	28 (28.00%)	0.3495
Dyspnea within 30 days, n (% of group)	69 (9.52%)	51 (8.16%)	18 (18.00%)	0.0018*
COPD, n (% of group)	54 (7.45%)	50 (8.00%)	4 (4.00%)	0.1572
Ventilator requirement within 48 h, n (% of group)	1 (0.14%)	1 (0.16%)	0 (0.00%)	0.6890
Pneumonia, n (% of group)	3 (0.41%)	3 (0.48%)	0 (0.00%)	0.4875
Dialysis, n (% of group)	1 (0.14%)	1 (0.16%)	0 (0.00%)	0.6890
Weight loss > 10% in last 6 months, n (% of group)	141 (19.45%)	125 (20.00%)	16 (16.00%)	0.3481
Disseminated cancer, n (% of group)	20 (2.76%)	17 (2.72%)	3 (3.00%)	0.8739
Received chemotherapy, n (% of group)	536 (73.93%)	461 (73.76%)	75 (75.00%)	0.7931
Received radiation, n (% of group)	515 (71.03%)	440 (70.40%)	75 (75.00%)	0.3464
Bleeding disorder, n (% of group)	22 (3.03%)	21 (3.36%)	1 (1.00%)	0.2015
Preop transfusion (<72 h before surgery), n (% of group)	1 (0.14%)	1 (0.16%)	0 (0.00%)	0.6890
Open or infected wound, n (% of group)	3 (0.41%)	3 (0.48%)	0 (0.00%)	0.4875
Diabetes, n (% of group)	124 (17.10%)	101 (16.16%)	23 (23.00%)	0.0917
Steroid or immunosuppressive therapy within 30 days, n (% of group)	16 (2.21%)	15 (2.40%)	1 (1.00%)	0.3763
Albumin <3.5 g/dL, n (% of group)	112 (15.45%)	94 (15.04%)	18 (18.00%)	0.4470
Bilirubin >1.2 mg/dL, n (% of group)	15 (2.07%)	11 (1.76%)	4 (4.00%)	0.1440
Creatinine > 1.2 (M) or > 1.1 (F) mg/dL, n (% of group)	61 (8.41%)	57 (9.12%)	4 (4.00%)	0.0868
Hematocrit < 30%, n (% of group)	29 (4.00%)	27 (4.32%)	2 (2.00%)	0.2717
INR > 1.4, n (% of group)	4 (0.55%)	3 (0.48%)	1 (1.00%)	0.5145
Platelet < 100,000/mcL, n (% of group)	19 (2.62%)	16 (2.56%)	3 (3.00%)	0.7982
WBC > 11,000/mcL, n (% of group)	13 (1.78%)	10 (1.60%)	3 (3.00%)	0.3273

functional health status prior to surgery (3.00% versus 0.64%, p = 0.0250) within the RAMIE group. A significant difference in preoperative clinical N stage was found between groups (p = 0.0214). All other preoperative comorbidity and TNM staging characteristics (Table 2) were similar between groups.

Analysis of postoperative outcomes is summarized in Table 3. Univariate analysis showed that length of hospital stay for RAMIE was shorter than for MIE (10.4 versus 11.5 days, p = 0.0002). This difference was not observed on multivariate analysis (difference in means −1.5 days, 95% CI -3.41 − 0.38, p = 0.1171). Univariate analysis also revealed that RAMIE operating time was longer compared to MIE (444.6 versus 417.9 min, p = 0.0415). No difference in operating time between groups was found on multivariate analysis (difference in means 6.43 min, 95% CI -19.93–32.78, p = 0.6323). No other significant differences were found on unadjusted analysis of outcome variables. RAMIE was not found to be an independent risk or protective factor for postoperative mortality (OR 1.50, 95% CI 0.38–6.00, p = 0.5675) or overall morbidity (OR 0.65, 95% CI 0.40–1.06, p = 0.0818). No significant differences were found between groups for systemic, organ-specific, or surgical complications. The most common complications were pulmonary (11.00% versus 18.72%, OR 0.56, 95% CI 0.28–1.12, p = 0.0988) and anastomotic leak (14.00% versus 15.36%, OR 0.85, 95% CI 0.44–1.62, p = 0.6118). The rates of unplanned conversion to open procedure were also similar between groups (OR 1.07, 95% CI 0.51–2.26, p = 0.8540), and no difference was observed in the rate of readmission (OR 1.67, 95% CI 0.91–3.06, p = 0.1001) or reoperation (OR 1.03, 95% CI 0.56–1.90, p = 0.93). Similar rates of positive resection margins were observed in both procedures (6.00% versus 6.62%; OR 0.76, 95% CI 0.30–1.92, p = 0.5616). Comparisons of pathologic TNM staging and pathologic diagnosis characteristics are presented in Table 2, and no differences in pathologic staging or diagnosis were found between RAMIE and MIE.

Discussion

Esophagectomy is a complex and high-risk surgery associated with significant morbidity and mortality. The procedure remains a principal method of treatment for esophageal cancer. Recognition of the high complication burden has led to the steady adoption of minimally-invasive approaches over open techniques, and previous studies have suggested MIE is associated with decreased complication rate, less blood loss, shorter hospital stay, and comparable disease-free survival.[4,10,11] Following a similar trend as MIE, RAMIE is being performed with increasing frequency.[3] Proposed advantages of RAMIE over MIE include reduced surgical trauma and improved operative technical ability, which theoretically result in superior outcomes.

In this study, we retrospectively analyzed data from the ACS-NSQIP database to assess for differences in short-term outcomes between RAMIE and MIE performed for the treatment of esophageal cancer. Our analysis indicates the two surgical approaches have similar rates of morbidity and mortality. There were no significant differences in systemic, organ-specific, or surgical complication rates. Both approaches had similar operating times, length of hospital stay, and rates of readmission and reoperation. These findings suggest that RAMIE may be considered as a feasible but non-superior option for treatment of esophageal cancer.

We found that both RAMIE and MIE had comparable rates of morbidity, with the most common being pulmonary complications

Table 2
Clinical TNM staging, pathologic TNM staging, and pathologic diagnosis characteristics for RAMI and MIE. *p < 0.05.

	All	MIE	RAMIE	p-value
Clinical T stage				
T0/Tis/Tx	20 (4.33%)	17 (4.37%)	3 (4.11%)	0.4017
T1	57 (12.34%)	50 (12.85%)	7 (9.59%)	
T2	95 (20.56%)	84 (21.59%)	11 (15.07%)	
T3	285 (61.69%)	233 (59.90%)	52 (71.23%)	
T4	5 (1.08%)	5 (1.29%)	0 (0.00%)	
Clinical N Stage				
N0/Nx	237 (51.30%)	209 (53.73%)	28 (38.36%)	0.0214*
N1	160 (34.63%)	124 (31.88%)	36 (49.32%)	
N2	58 (12.55%)	51 (13.11%)	7 (9.59%)	
N3	7 (1.52%)	5 (1.29%)	2 (2.74%)	
Clinical M Stage				
M0/Mx	462 (98.70%)	383 (98.46%)	73 (100%)	0.2855
M1	6 (1.30%)	6 (1.54%)	0 (0.00%)	
Pathologic T Stage				
T0/Tis/Tx	90 (18.99%)	70 (17.50%)	20 (27.03%)	0.0684
T1	116 (24.47%)	102 (25.50%)	14 (18.92%)	
T2	88 (18.57%)	69 (17.25%)	19 (25.68%)	
T3	174 (36.71%)	154 (38.50%)	20 (27.03%)	
T4	6 (1.27%)	5 (1.25%)	1 (1.35%)	
Pathologic N Stage				
N0/Nx	290 (61.18%)	241 (60.25%)	49 (66.22%)	0.5899
N1	103 (21.73%)	91 (22.75%)	12 (16.22%)	
N2	61 (12.87%)	52 (13.00%)	9 (12.16%)	
N3	20 (4.22%)	16 (4.00%)	4 (5.41%)	
Pathologic M Stage				
M0/Mx	467 (98.52%)	394 (98.50%)	73 (98.65%)	0.9224
M1	7 (1.48%)	6 (1.50%)	1 (1.35%)	
Pathologic Diagnosis				
Adenocarcinoma	527 (72.69%)	459 (73.44%)	68 (68.00%)	0.1485
SCC	63 (8.70%)	55 (8.80%)	8 (8.00%)	
Dysplasia	18 (2.50%)	12 (1.92%)	6 (6.00%)	
No malignancy	99 (13.70%)	83 (13.28%)	16 (16.00%)	
Other/Unknown	18 (2.48%)	16 (3.49%)	2 (2.00%)	

and anastomotic leak. The impact of minimally-invasive techniques to reduce pulmonary complication rate in comparison to open esophagectomy is well established, but a significant reduction in pulmonary complications with RAMIE compared to MIE has not been demonstrated.[4,12,13,17,20,21] Recent case series have shown that the incidence of pulmonary complications with RAMIE is relatively high with reported frequencies of up to 42%.[22] The similar rates of pulmonary complications with RAMIE and MIE in our study is conceivably related to their shared fundamental anatomic and physiologic principles. Additionally, both approaches had similar lengths of operative time, and thus, are likely to have had similar risks for postoperative pulmonary effects related to ventilatory support during the procedure.[17,23]

Anastomotic leak in the mediastinum is arguably the most serious complication associated with esophagectomy and has been shown to significantly increase mortality, length of hospital stay, and associated healthcare costs.[24,25] While we found no improvement in leak rate with RAMIE, we were unable to assess for any association between differences in leak rate and the site or anastomosis technique used as this information was not available in the NSQIP database. Previous studies have suggested a stapled method results in lower leak rates with cervical anastomosis, and it is very likely the anatomic location and type of anastomosis technique influence risk for anastomotic leak complications.[26] We were also unable to evaluate any possible effect that the use of fluorescent intraoperative imaging had on avoiding anastomotic ischemia during robotic surgery as the use of this technology is not reported in the NSQIP database.

A theoretical advantage of RAMIE over MIE is improved surgical precision during resection resulting in better oncologic outcomes, and failure to obtain negative resection margins is associated with higher rates of cancer recurrence and decreased overall survival.[27,28] We found no difference in the rate of positive resection margins or short-term survival between RAMIE and MIE. Prior studies have reported the adequacy of resection with RAMIE to range from 81 to 98%, and similar to our analysis, no previous studies have shown a difference in positive resection margin frequency between RAMIE and MIE.[3,6,9,29] Evidence for improved surgical precision with RAMIE has been suggested by several studies showing higher lymph node dissection yield either in total or along the left recurrent laryngeal nerve, suggesting RAMIE is possibly better suited than MIE for complicated cases with locoregional lymph node involvement.[16,17,21] However, other studies have found no significant difference in the number of lymph nodes dissected with RAMIE compared to MIE.[3,9,14,15] Unfortunately, we were unable to assess for differences in harvested lymph node

Table 3
Postoperative outcomes for RAMIE and MIE. *p < 0.05.

Morbidity/Mortality	Univariate Analysis				Multivariate Analysis	
	All	MIE	RAMIE	p-value	Adjusted OR for RAMIE (95% CI)	p-value
n (% of total)	725 (100%)	625 (86.21%)	100 (13.79%)			
Mortality, n (% of group)	17 (2.34%)	14 (2.24%)	3 (3.00%)	0.6410	1.50 (0.38–6.00)	0.5674
Overall morbidity, n (% of group)	276 (38.07%)	245 (39.20%)	31 (31.00%)	0.1169	0.65 (0.40–1.06)	0.0818
Cardiac (arrest or MI), n (% of group)	12 (1.66%)	12 (1.92%)	0 (0.00%)	0.1623	n too small for analysis	
Pulmonary (pneumonia, ventilator > 48 h, or reintubation), n (% of group)	128 (17.66%)	117 (18.72%)	11 (11.00%)	0.0601	0.56 (0.28–1.12)	0.0988
Renal failure or insufficiency, n (% of group)	9 (1.24%)	9 (1.44%)	0 (0.00%)	0.2272	n too small for analysis	
VTE (DVT or PE), n (% of group)	31 (4.28%)	28 (4.48%)	3 (3.00%)	0.4970	0.63 (0.18–2.22)	0.4680
Wound (superficial SSI, organ space SSI, or dehiscence), n (% of group)	107 (14.76%)	95 (15.20%)	12 (12.00%)	0.4022	0.60 (0.29–1.22)	0.1533
Sepsis or septic shock, n (% of group)	67 (9.24%)	59 (9.44%)	8 (8.00%)	0.6443	0.69 (0.31–8.58)	0.5725
Bleeding requiring transfusion, n (% of group)	71 (9.79%)	61 (9.76%)	10 (10.00%)	0.9402	0.96 (0.44–2.10)	0.9094
Positive resection margins, n, (% of group)	48 (6.62%)	42 (6.72%)	6 (6.00%)	0.9457	0.76 (0.30–1.92)	0.5616
Anastomotic leak, n (% of group)	110 (15.17%)	96 (15.36%)	14 (14.00%)	0.7249	0.85 (0.44–1.62)	0.6118
Converted to open, n (% of group)	64 (8.83%)	53 (8.48%)	11 (11.00%)	0.4095	1.07 (0.51–2.26)	0.8540
Readmission, n (% of group)	91 (12.55%)	73 (11.68%)	18 (18.00%)	0.0765	1.67 (0.91–3.06)	0.1001
Return to OR, n (% of group)	119 (16.41%)	102 (16.32%)	17 (17.00%)	0.8647	1.03 (0.56–1.89)	0.9304
Discharge to home, n (% of group)	632 (87.17%)	548 (87.68%)	84 (84.00%)	0.3069	0.90 (0.47–1.73)	0.7499
					Difference with RAMIE (95% CI)	
Length of stay, days, mean ± SD	11 ± 8.61	12 ± 8.31	10 ± 10.32	0.0002*	−1.5 (−3.41–0.38)	0.1171
Operating time, minutes, mean ± SD	422 ± 124.66	418 ± 126.30	445 ± 111.80	0.0415*	6.4 (−19.92–32.78)	0.6312

dissection count between RAMIE and MIE as this variable is not reported in the NSQIP database. Further investigation is necessary to better understand the differences in oncologic outcomes between RAMIE and MIE, particularly in regard to the utility of robotic-assistance for lymph node dissection.

Our finding of similar rates of unplanned conversion to open procedure between RAMIE and MIE suggests comparable frequencies of intraoperative complications between the two procedures. In previous studies on MIE, the most common causes for unplanned conversions were intraoperative recognition of pleural or peritoneal adhesions, tumor invasion, non-radical resection, or excessive bleeding.[30,31] Assuming similar causes for conversion occur with RAMIE, the technical advantages of robotic-assistance, such as three-dimensional viewing and high degree of freedom of movement, may not be effective in preventing conversion in these scenarios.

A current disadvantage to RAMIE is added operational costs associated with use of robotic-assistance. In the United States, the overall healthcare costs for treatment of esophageal cancer is estimated to be over $150,000 during the last year of life alone, and potential additional costs from RAMIE could be considerably taxing on the healthcare system.[18,32] While a comprehensive cost analysis of RAMIE and MIE has not been performed, studies on other types of minimally-invasive thoracic surgery have demonstrated significantly increased costs associated with robotic use.[33] A primary concern related to the cost of RAMIE is longer operating times, which has been attributed to additional time requirements for docking the instrument as well as a “learning curve” effect related to individual surgeon experience.[29,34,35] However, our analysis showed no difference in operating time between the two approaches suggesting the operational efficiency of RAMIE is comparable to MIE, and thus, the concerns regarding cost difference between RAMIE and MIE are possibly misplaced. Regardless, it is clear a thorough comparative analysis on the cost effectiveness of RAMIE versus MIE is needed.

Our retrospective study has several limitations that warrant acknowledgment. First, our analysis is of only two years of data from 2016 to 17 as these are the first to contain information on the use of robotic assistance. Additionally, we were only limited to assessing variables collected within the NSQIP database, and the outcomes examined were all within 30 days of surgery. Further data collection on long-term outcomes, particularly morbidity, oncologic recurrence, and disease-free survival, would be instrumental for further comparisons of RAMIE and MIE. We also recognize that we were unable to control for the effect of surgeon experience in our analysis. While RAMIE was first described over fifteen years ago, only recently has the procedure been performed more frequently, and thus, the effect of a learning curve with RAMIE may influence the observed outcomes in ways we cannot account for. Finally, we did not evaluate for potential differences between the respective surgical technique (e.g., transhiatal, Ivor-Lewis, McKeown) within the RAMIE and MIE cohorts, and therefore, we were unable to account for the possible impact of variation in technique on postoperative outcomes.

Conclusions

No significant difference was found in the incidence of 30-day postoperative outcomes between RAMIE and MIE. In comparison to MIE, RAMIE may be considered a feasible but non-superior option for treatment of esophageal cancer.

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