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Nationwide analysis of short-term surgical outcomes of minimally invasive esophagectomy for malignancy

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Abstract

Background—Minimally invasive esophagectomy (MIE) is being increasingly utilized for esophageal cancer. It is unclear if MIE if being safely performed with satisfactory outcomes across the USA. We aimed to analyze the short-term surgical outcomes of MIE as compared to open esophagectomy (OE).

Methods—The National Cancer Database (NCDB) was queried for patients who underwent MIE or OE for esophageal malignancy between 2010 and 2011. Margin positivity, lymph node retrieval, 30-day mortality, 30-day unplanned readmission rate and hospital length of stay.

Results—A total of 4047 patients were identified; 3050 (75.4%) underwent OE, and 997 (24.6%) underwent MIE. The proportion of MIE increased from 21.9% in 2010 to 27.4% in 2011 ($p < 0.001$). The conversion rate was 13.7%. There were no differences in-patient or tumor characteristics between the two cohorts. OE and MIE were comparable in terms of margin positive resection rate (7.4% vs. 8.1%, $p = 0.48$), 30-day unplanned readmission rate (7.6% vs. 7.2%, $p = 0.64$) and 30-day mortality rate (4.3% vs. 3.3%, $p = 0.71$). Compared to OE, MIE was associated with higher node retrieval (median 12 vs 14, $p < 0.001$), and shorter hospital stay (median 11.0 vs 10.0 days, $p < 0.001$). Logistic regression analysis showed that surgical approach (OE vs MIE) was not associated with 30-day mortality rate. In an ANCOVA analysis, MIE was independently associated with a shorter hospital stay compared to OE (estimated mean difference 1.57 ± 0.53

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Ethical approval

National Cancer Database study – no Ethics/IRB approval required.

Author contribution

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Kristopher Attwood – study design, statistical analysis and writing, review.
Moshim Kukar – study design, manuscript writing and final review.
Steven Hochwald – conception, study design, data analysis, manuscript writing, final review.
Steven Nurkin – conception, study design, data collection, data analysis, manuscript writing, final review.

Conflicts of interest

None for all authors.

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days, p = 0.003). MIE patients who underwent conversion had a longer hospital stay compared to those who did not (11.0 vs 10.0 days, p = 0.02).

Conclusion—MIE is being offered more frequently to patients with esophageal cancer, and maybe accompanied with better short-term outcomes including shorter hospital stay when compared to open esophagectomy.

Keywords

Esophagectomy; Laparoscopic; Minimally-invasive

1. Introduction

Esophageal cancer (EC) is the eighth most common cancer worldwide, affecting nearly 450,000 people globally [1]. In 2014, the incidence of EC in the US was 18,170, with 15,450 deaths [2]. It is one of the leading causes of cancer-related mortality among males [2]. The prognosis is poor, with a 5-year overall survival (OS) rate of 16.9% [3]. The prognosis depends on the extent of disease at presentation, with 5-year survival rates of 37.8% and 19.8% for patients who present with localized and regional disease, respectively [3]. The most definitive treatment for patients with resectable (i.e., localized/regional) disease is a multimodality approach that includes a combination of concurrent chemoradiation and surgical resection [1,4]. Esophageal resection is associated with significant morbidity and mortality [5–8].

Given the overall poor prognosis of EC, there has been an interest among surgeons to improve surgical morbidity, allowing for prompt initiation of adjuvant therapy and to enhance quality of life. With the advent of laparoscopic approaches for upper gastrointestinal and thoracic procedures, minimally invasive esophagectomy (MIE) is being increasingly considered an option to further optimize surgical outcomes [9,10]. Since the safety and feasibility of laparoscopic esophageal resections was first reported in the 1990s, there have been multiple studies comparing open and minimially invasive approaches [11–15]. In general, these studies favored the minimally invasive approach over the traditional open approach, characterizing fewer pulmonary complications and postoperative morbidity. However, most of these studies were reported by few skilled laparoscopic surgeons. It is not clear if these results can be replicated nationally. Thus, we aimed to perform a nationwide analysis of the short-term surgical outcomes of MIE, and assess its safety and feasibility through unselected reporting. We hypothesized that MIE is a safe approach to esophageal resection for malignancy, compared to the traditional open approach.

2. Methods

2.1. Data extraction

The National Cancer Database (NCDB) is a comprehensive nationwide database created by the joint efforts of the American Cancer Society (ACS) and the Commission on Cancer (CoC) in 1989. The NCDB captures more than 70% of all invasive cancers in the US, and has a standardized system of reporting overall survival data and 30-day outcomes following surgical procedures up until 2011. Since 2010, the NCDB has been collecting data regarding

the surgical approach (i.e. minimally invasive vs. open) performed for esophageal resection. We extracted data for all patients who underwent esophagectomy between January 1, 2010 and December 31, 2011.

We excluded all patients who did not have microscopic confirmation of malignancy and patients whose primary tumor site involved the cervical esophagus. Data on patient demographics including age at diagnosis, sex, race, and insurance status were extracted. Data on the comorbidity status of the patient was reported using the Charlson–Deyo comorbidity score (CDCC), which was coded as '0', '1' or '2' for patients with none, one or more than one comorbid conditions, respectively. Tumor-specific data such as the tumor type, histological grade and pathological American Joint Committee on Cancer (AJCC) stage (7th Edition) were also extracted. The histological type of the tumor was coded in the database using the *International Classification of Diseases (ICD-O-3)* classification system, and we grouped them, as either "adenocarcinoma," "squamous cell" or "other". Using data available on the sequence of therapies (surgery, chemotherapy or radiation) performed as the first course of treatment at the reporting facility, receipt of neoadjuvant chemotherapy or radiation was included as a variable in the analyses.

The NCDB reports the surgical approach (open, laparoscopic or robotic) used for the most invasive, most definitive first course primary site procedure. We excluded all patients who had the surgical approach coded as "robotic" or "robotic converted to open." Patients whose surgical approach was coded as "endoscopic or laparoscopic" or "endoscopic or laparoscopic converted to open" were included under the Minimally Invasive Esophagectomy (MIE) cohort in this study. For comparison, we used patients whose surgical approach was coded by the NCDB as "open or approach unspecified" as the Open Esophagectomy (OE) cohort.

The outcomes recorded included 30-day mortality rate, margin status, number of lymph nodes examined in the specimen, hospital length of stay (LOS) and 30-day unplanned readmission rate. We excluded all patients who did not have the surgical procedure of the primary site done at the reporting facility or if it was unknown whether the surgery of the primary site was performed at the reporting facility.

2.2. Statistical analysis

Patient-, tumor- and treatment-related variables were reported using means, medians and standard deviations for continuous variables, and using frequencies and relative frequencies for categorical variables. Comparisons were made using t-test and Fisher's exact test for continuous and categorical variables respectively. The association between these variables and 30-day mortality was analyzed using a logistic regression model; the models were fit using Firth's penalized function and reported as Hazards Ratios (HR), with the corresponding 95% Confidence Intervals (CI). An Analysis of Covariance (ANCOVA) model was used to evaluate the difference in mean length of hospital stay between OE and MIE cohorts. All analyses were conducted using SAS v9.4 (Cary, NC), and an alpha value of 0.05 was used to determine statistical significance.

3. Results

3.1. Comparison of patient and tumor characteristics

There were a total of 4047 patients, of which 3050 patients (75.4%) were in the OE cohort, and 997 patients (24.6%) in the MIE cohort. Patient- and disease-related characteristics were compared between the two cohorts (Table 1). The mean age of the study cohort was 63.2 (+/−9.9) years, and a majority of patients (77%) had adenocarcinoma. There was no difference in the mean age, sex, racial distribution or insurance status between the two groups. There was a slight but statistically significant higher proportion of patients with Hispanic origin in the OE cohort (3.5% vs 2.0%, p = 0.02). The proportion of esophagectomies performed laparoscopically increased from 21.9% in 2010 to 27.4% in 2011 (P < 0.001). There were no differences in the overall distribution of histological type, grade of the tumor, or pathological stage distribution. Patients in both cohorts were similar in terms of the distribution of severity of comobidity status, and receipt of neoadjuvant chemotherapy and radiation (see Table 2).

3.2. Comparison of surgical outcomes based on surgical approach

We compared the surgical outcomes between OE and MIE cohorts using univariate analysis. There was no difference in the rate of positive margins, but the median number of nodes examined in the surgical specimen was higher with MIE compared to OE (14 vs 12, p < 0.001). Median hospital LOS was also shorter with MIE compared to OE (10.0 days vs 11.0 days, p < 0.001). The overall 30-day unplanned readmission and mortality rates were 7.5% and 4.1% respectively, with no difference in these outcomes between the two groups. We then performed a multivariate analysis using a logistic regression model to study the predictive factors independently associated with 30-day mortality rate while controlling for all variables (Table 3). Age (HR = 1.03, 95% CI 1.01–1.06, for every 1 year increase, p = 0.014) and a margin-positive resection (HR = 2.57, 95% CI 1.50–4.41, p = <0.001) were the only two predictive factors independently associated with 30-day mortality. Although patients with two or more comorbidities were associated with a higher 30-day mortality, this variable approached but did not reach statistical significance (HR = 2.01, 95% CI 1.10–3.66, p = 0.08). Surgical approach (OE vs MIS) did not emerge as an independent factor associated with 30-day mortality rate.

Next, we employed an ANCOVA model to evaluate the differences in hospital LOS between the two cohorts, while adjusting for other pre-operative patient characteristics. In this analysis, the estimated mean LOS was 14.39 ± 3.40 days and 15.95 ± 3.37 days for MIE and OE cohorts, respectively (p = 0.003).

3.3. Analysis of MIE patients who underwent conversion to open surgery

Of 997 MIE patients, 134 (13.4%) underwent conversion to open surgery. We compared the characteristics of MIE patients who underwent conversion to open surgery with those who did not (Table 4). Overall, there were no differences between the two groups. Of note, compared to MIE patients who did not undergo conversion, those who did undergo conversion to open surgery were more likely to be non-Caucasian, have a non-

adenocarcinoma histology and a higher Charlson–Deyo comorbidity score. However, these associations approached but did not reach statistical significance (see Table 5).

The conversion rate also dropped from 15.8% in 2010 to 11.6% in 2011, but again this trend approached but did not reach statistical significance (p = 0.06). We then compared the surgical outcome measures between MIE patients who underwent conversion and those who did not. The median hospital LOS was slightly higher in those who underwent conversion (10.0 vs 11.0 days, p = 0.015). There were no differences in the margin positive rate, median number of nodes examined, 30-day unplanned readmission or 30-day mortality rate.

4. Discussion

This study has demonstrated the safety of MIE being performed in the US. The findings of our study are better appreciated with an understanding of the evolution of surgical techniques for esophageal resection. The benchmark for open surgical approach was set by Orringer et al., who in 1999 reported a hospital mortality and morbidity rate of 4% and 13% respectively and an anastomotic leak rate of 9%, in a series of 1085 patients that underwent open transhiatal esophagectomy [16]. However, the mortality rate from large multi-institutional studies and nationwide data showed that there was gross variation in surgical outcomes, with mortality rates as high as 23% across the US [7,8,17]. By this time, there was increasing interest for minimally invasive approaches following earlier reports of laparoscopic esophagectomy through right thoracoscopic and transhiatal approaches by Cuschieri et al. and DePaula et al., respectively [13,14].

In 1998, just prior to Orringer's report, Luketich et al. described their early experience of MIE in 8 patients, with no mortalities [11]. Luketich continued to pioneer the use of laparoscopic approaches – in their first major report of 222 patients in 2003. They reported a mortality rate of 1.4%, with an anastomotic leak rate of 11.7%, thereby demonstrating the safety and feasibility of laparoscopic esophagectomy [12]. In this study, they described multiple approaches ranging from a combination of right thoracoscopic and laparscopic transhiatal technique to an Ivor-Lewis type intrathoracic anastomoses. Following this, there have been several single-institutional studies reporting the safety and feasibility of MIE, using a variety of surgical techniques [18–21]. In 2012, Kfir Ben David et al. reported mortality rate less than 1% and anastomotic leak rate of 4% using a three-field approach of right thoracoscopic esophageal mobilization, laparoscopic gastric mobilization/conduit formation, and a cervical anastomosis using a linear stapled technique via a left lateral neck incision [22]. Luketich et al. reported a series of 1033 MIE patients with a similar mortality of 1.4% [23]. In this study, they reported that the outcomes of MIE with neck anastomosis and an Ivor-Lewis type intrahoracic anastomosis were similar, but with a lower recurrent laryngeal nerve injury rate with the latter. Interestingly, Orringer et al. had published their updated results of over 2000 MIE patients, reporting a low mortality rate of 1% [24].

Multiple other institutional studies showed a wide range of outcomes in terms of mortality and anastomotic leak rate among MIE patients, but not consistently as low as open esophagectomies from Orringer's series [25]. Thus, the data seemed to be equipoised between open and MIE approaches, with high-volume and expert surgeons demonstrating

comparable outcomes using either technique. At this time, Bierre et al. reported the outcomes of a multicenter, open-label randomized controlled trial between OE and MIE for resectable EC, which favored MIE (29% vs 9%) for the primary endpoint of the study, namely pulmonary infection within 2 weeks of surgery [15]. Systematic reviews and meta-analyses also seemed to favor MIE in terms of shorter length of stay and lower morbidity primarily due to decreased pulmonary complications [26–29].

Most recently, Luketich et al. reported the results of a prospective Phase II multicenter trial of the Eastern Cooperative Oncology Group (E2202) study for MIE [30]. In this study of 95 patients who underwent MIE per protocol, the 30-day mortality rate was 2.1%, median hospital LOS 9 days, the median number of nodes retrieved 19, and the R0 resection rate 96%. While all these results are certainly encouraging, most of these studies that form the basis of the argument that MIE is safe and feasible are reported by highly skilled laparsocopic surgeons. Given the publication bias, it is not certain if MIE, a relatively new complex procedure requiring advanced laparoscopic skills is being done at the national level in the US, with acceptable results.

Our study demonstrated certain important findings – (1) MIE is being increasingly performed in the US, although the vast majority (nearly three-fourths) of all esophageal resections are still being done using the open approach, (2) MIE is being safely performed with short term outcomes comparable to the traditional open approach performed during the same time period,(3) the technical adequacy of MIE appears satisfactory, (4) there is a small but definite benefit to MIE in terms of shorter hospital LOS and, (5) conversion to open surgery occurs at rates similar to those reported in other large series, and is not associated with significant differences in surgical outcomes when compared with those patients who underwent MIE successfully, except for a minor prolongation in hospital length of stay.

Our study has important limitations. First is the lack of granularity in the database. We do not have access to the actual operative reports which is necessary to discern if minimally invasive approach was used for the thoracic or abdominal portion of the operation or both. Details of whether a transhiatal or transthoracic technique was used was also unavailable. The Current Procedure Terminology (CPT) codes are not available in the database, which results in heterogeneity in the type of surgical approach performed, i.e it is not known if the approach was purely laparoscopic, or hand-assisted, or hybrid in nature. The causes for conversion are also not available in the database, hence outcomes could be compared only from the ‘intention to treat’ standpoint. However, most other major reports on MIE do include a combination of techniques, and are often considered to be comparable in outcomes. Secondly, complications specific to esophagectomy such as anastomotic leak rate, pulmonary complications and atrial fibrillation are not available in the database.

Another limitation is selection bias, which is inherent to all retrospective “big-data” analayses. We addressed this limitation by comparing the two patient cohorts (OE and MIE) using univariate analysis. We did not find any meaningful difference between the groups that could have contributed to selection bias. Hence, it might be safe to presume that MIE offered currently in the US is being done so, with indications similar to the traditional open

approach, based on the absence of major differences in the patient and tumor characteristics between the two groups.

The mortality rates of OE and MIE were 4.3% and 3.3% respectively, which were not statistically significant. Even after controlling for other factors in a multivariate analysis, surgical approach was not associated with 30-day mortality. These numbers are similar to the 30-day mortality rates reported in a population study in the UK, where the reported rates were 4.3% and 4.0% for OE and MIE respectively [31]. The 30-day mortality rate of MIE nationwide in our study is comparable to the mortality rate reported in the E2202 Phase II study (2.9%) done in the US[30], despite a more favorable selection of patients under protocol in the latter study. This suggests that MIE that is being performed in the US is being done safely, despite being offered to a similar patient population.

Our study demonstrated a shorter hospital LOS with MIE, although this difference is relatively small (only 1 day). This difference seems to be internally consistent, as MIE patients who underwent conversion to open surgery also had a hospital stay 1 day longer than those who did not. In the only randomized trial comparing OE and MIE, there were less pulmonary compications with MIE, which was reflected in the shorter hospital LOS by 3 days (14 vs 11 days) [15]. The lower difference in the hospital LOS nationwide may be due to more heterogeneity and high risk patient selection compared to patients recruited for clinical trails. Furthermore, in large centers specializing in MIE, the hospital LOS may be shorter due to strict adherance to early recovery pathways unique to those institutions [22]. We contend that despite the obvious advantages of minimally invasive approaches, the actual operative procedure is equally extensive with either approach that the nationwide hospital LOS could be reduced but not by more than 2–3 days even if MIE is being offered widely and routinely to all patients requiring esophageal resection for malignancy. The NCDB database does not have information on hospital costs and hence the analysis on the economic impact of MIE was not possible.

Finally, the technical adequacy of MIE seems to be satisfactory compared to the open approach in terms of margin positive rate and extent of lymphadenectomy. Interestingly, the median number of examined lymph nodes was higher with MIE, which may be due to better exposure with MIE of the mediastinal nodes leading to more deliberate lymph node dissections compared to open approaches, especially with the transhiatal technique. Another possible explanation could that surgical groups performing MIE are better motivated to work with their pathology colleagues to examine and reexamine the pathological specimens exhaustively to ensure adequate node retrieval. Nevertheless, the median number of nodes examined in either groups within this national database seems to be lesser than those reported in other institutional studies [30,32]. Although there is not enough follow-up available on these patients to analyze oncological outcomes, the technical adequacy of MIE could serve as surrogate marker for acceptable oncological outcomes. There was also a trend towards lower conversion rate during the study period, along with a higher proportion of esophagectomies being done minimally invasively. This suggests a trend towards increased utilization of minimally invasive approaches for esophageal cancer surgery, and possibly a better position on the learning curve resulting in lower conversion rate.

In summary, we conclude that minimally invasive approach to esophageal resection for malignancy using laparoscopic techniques has comparable short-term surgical results compared to the traditional open approach, with the additional benefit of decreased hospital LOS. Robotic approaches are on the horizon, and further dedicated studies comparing robotic to laparoscopic esophagectomies are warranted.

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HIGHLIGHTS

- Minimally invasive esophagectomy (MIE) is being increasing used for surgical resection of esophageal malignancies in the USA.
- MIE is being safely performed with equivalent technical adequacy and short-term outcomes when compared to open esophagectomy.
- MIE may be associated with a slightly shorter hospital length of stay compared to open esophagectomy.

Table 1

Comparison of patient and tumor characteristics of the study population.

Patient/Tumor characteristic		MIE N (%)	OE N (%)	All patients N (%)	P-value
Number of patients		997 (24.6)	3050 (75.4)	4047 (100%)	
Age	Mean (+/−SD)	63.3 (+/−9.6)	63.1 (+/−9.9)	63.2 (+/−9.9)	0.77
Sex	Male	838 (84.1%)	2498 (81.9%)	3336 (82.4%)	0.12
	Female	159 (15.9%)	552 (18.1%)	711 (17.6%)	
Race	White	926 (93.7%)	2784 (92.2%)	3710 (92.6%)	0.30
	Black	45 (4.6%)	173 (5.7%)	218 (5.4%)	
	Other	17 (1.7%)	61 (2.0%)	78 (1.9%)	
Insurance	Not insured	21 (2.1%)	57 (1.9%)	78 (2.0%)	0.07
	Private/Managed care	476 (48.5%)	1299 (43.9%)	1775 (45.1%)	
	Medicaid	49 (5.0%)	186 (6.3%)	235 (6.0%)	
	Medicare	425 (43.3%)	1372 (46.4%)	1797 (45.6%)	
	Other government	10 (1.0%)	45 (1.5%)	55 (1.4%)	
Origin	Non-Hispanic	937 (98.0%)	2813 (96.5%)	3750 (96.9%)	0.02
	Hispanic	19 (2.0%)	101 (3.5%)	120 (3.1%)	
Behavior	In-situ cancer	12 (1.2%)	36 (1.2%)	48 (1.2%)	0.95
	Invasive cancer	985 (98.8%)	3014 (98.8%)	3999 (98.8%)	
Year of diagnosis	2010	438 (21.9%)	1566 (78.1%)	2004 (49.5%)	<0.001
	2011	559 (27.4%)	1484 (72.6%)	2043 (50.5%)	
CDCC score[+]	0	710 (71.2%)	2184 (71.6%)	2894 (71.5%)	0.84
	1	224 (22.5%)	689 (22.6%)	913 (22.6%)	
	2	63 (6.3%)	177 (5.8%)	240 (5.9%)	
Histological type	Adenocarcinoma	793 (79.5%)	2324 (76.2%)	3117 (77.0%)	0.07
	Squamous cell	166 (16.6%)	574 (18.8%)	740 (18.3%)	
	Other	38 (3.8%)	152 (5.0%)	190 (4.7%)	
Grade	Well-differentiated	84 (9.8%)	203 (7.8%)	287 (8.3%)	0.19
	Moderately differentiated	369 (43.1%)	1101 (42.1%)	1470 (42.3%)	
	Poorly differentiated	381 (44.5%)	1235 (47.2%)	1616 (46.5%)	
	Undifferentiated	22 (2.6%)	77 (2.9%)	99 (2.9%)	

Patient/Tumor characteristic		MIE N (%)	OE N (%)	All patients N (%)	P-value
AJCC Stage	0	268 (26.9%)	837 (27.4%)	1105 (27.3%)	0.81
	I	273 (27.4%)	806 (26.4%)	1079 (26.7%)	
	II	228 (22.9%)	743 (24.4%)	971 (24.0%)	
	III	212 (21.3%)	612 (20.1%)	824 (20.4%)	
	IV	16 (1.6%)	52 (1.7%)	68 (1.7%)	
Neoadjuvant chemotherapy	No	407 (41.1%)	1180 (39.0%)	1587 (39.5%)	0.24
	Yes	584 (58.9%)	1848 (61.0%)	2432 (60.5%)	
Neoadjuvant radiation	No	457 (46.0%)	1371 (45.4%)	1828 (45.5%)	0.73
	Yes	537 (54.0%)	1652 (54.6%)	2189 (54.5%)	

*Percentages are apportioned row-wise, i.e. according to the year of diagnosis

†Charlson–Deyo Comorbidity score. SD, Standard Deviation.

Table 2

Comparison of surgical outcomes between OE and MIE cohorts.

Surgical outcome	OE N (%)	MIE N (%)	All patients N (%)	P-value
Margin positive rate	220 (7.4%)	80 (8.1%)	300 (7.6%)	0.48
Median number of nodes examined	12	14	12	<0.001
Median hospital length of stay	11.0	10.0	10.0	<0.001
Unplanned readmission rate [+]	230 (7.6%)	71 (7.2%)	301 (7.5%)	0.64
Mortality rate [+]	131 (4.3%)	33 (3.3%)	164 (4.1%)	0.17

[+] Event occurring within 30 days after surgery.

Table 3

Multivariate analysis to predict independent factors associated with 30-day mortality.

Variable		Overall Mortality		P-value
		HR	95% CI	
Age (for every 1 year increase)		1.03	1.01, 1.06	0.01
Sex	Male	1.0	(Reference)	0.76
	Female	0.93	0.57, 1.51	
Race	White	1.0	(Reference)	0.95
	Black	0.92	0.41, 2.07	
	Other	1.15	0.32, 4.06	
Insurance	Not insured	1.0	(Reference)	0.44
	Private/Managed care	2.62	0.95, 7.24	
	Medicaid	1.36	0.61, 3.04	
	Medicare	1.15	0.72, 1.82	
	Other government	1.07	0.21, 5.58	
Origin	Non-Hispanic	1.0	(Reference)	0.11
	Hispanic	1.95	0.85, 4.45	
Grade	Well differentiated	1.0	(Reference)	0.10
	Moderately differentiated	1.08	0.55, 2.11	
	Poorly differentiated	0.67	0.33, 1.36	
	Undifferentiated	0.46	0.11, 1.88	
Histological type	Adenocarcinoma	1.0	(Reference)	0.18
	Squamous cell carcinoma	1.20	0.73, 1.96	
	Other	2.03	1.10, 3.66	
CDCC score[+]	0	1.0	(Reference)	0.08
	1	1.12	0.73, 1.71	
	2	2.01	1.10, 3.66	
Behavior	In-situ cancer	1.0	(Reference)	0.70
	Invasive cancer	2.00	0.06, 69.55	
AJCC stage	Stage 0	1.0	(Reference)	0.19
	Stage I	0.61	0.35, 1.04	
	Stage II	0.75	0.46, 1.23	
	Stage III	0.53	0.30, 0.94	
	Stage IV	0.98	0.31, 3.16	
Year of diagnosis	2010	1.0	(Reference)	0.61
	2011	0.91	0.64, 1.30	
Margins	Negative	1.0	(Reference)	<0.001
	Positive	2.57	1.50, 4.41	
Neoadjuvant radiation	No	1.0	(Reference)	0.70
	Yes	1.16	0.55, 2.42	
Neoadjuvant chemotherapy	No	1.0	(Reference)	0.34
	Yes	0.70	0.33, 1.46	

Variable		Overall Mortality		P-value
		HR	95% CI	
Surgical approach	MIE	1.0	(Reference)	0.78
	OE	1.06	0.70, 1.62	

+Charlson–Deyo Comorbidity score. CI, confidence interval.

Table 4

Comparison of MIE patients who did not and who did undergo conversion to open surgery.

Patient/Tumor characteristic		Conversion		P-value
		No N (%)	Yes N (%)	
Number of patients		863 (86.6)	134 (13.4)	
Age	Mean (+/−SD)	63.3 (+/−9.7)	65.0 (+/−9.5)	0.81
Sex	Male	723 (83.8%)	115 (85.8%)	0.55
	Female	140 (16.2%)	19 (14.2%)	
Race	White	807 (94.3%)	119 (90.2%)	0.09
	Black	37 (4.3%)	8 (6.1%)	
	Other	12 (1.4%)	5 (3.8%)	
Insurance	Not insured	20 (2.4%)	1 (0.8%)	0.33
	Private/Managed Care	418 (49.2%)	58 (43.9%)	
	Medicaid	39 (4.6%)	10 (7.6%)	
	Medicare	363 (42.8%)	62 (47.0%)	
	Other government	9 (1.1%)	1 (0.8%)	
Origin	Non-Hispanic	817 (98.1%)	120 (97.6%)	0.70
	Hispanic	16 (1.9%)	3 (2.4%)	
Behavior	In-situ cancer	10 (1.2%)	2 (1.5%)	0.74
	Invasive cancer	853 (98.8%)	132 (98.5%)	
Year of diagnosis *	2010	369 (84.2%)	69 (15.8%)	0.06
	2011	494 (88.4%)	65 (11.6%)	
CDCC score +	0	621 (72.0%)	89 (66.4%)	0.10
	1	193 (22.4%)	31 (23.1%)	
	2	49 (5.7%)	14 (10.4%)	
Histological type	Adenocarcinoma	793 (79.5%)	2324 (76.2%)	0.07
	Squamous cell	166 (16.6%)	574 (18.8%)	
	Other	38 (3.8%)	152 (5.0%)	
Grade	Well-differentiated	84 (9.8%)	203 (7.8%)	0.19
	Moderately differentiated	369 (43.1%)	1101 (42.1%)	
	Poorly differentiated	381 (44.5%)	1235 (47.2%)	
	Undifferentiated	22 (2.6%)	77 (2.9%)	
AJCC Stage	0	230 (26.7%)	38 (28.4%)	0.09
	I	248 (28.7%)	25 (18.7%)	
	II	197 (22.8%)	31 (23.1%)	
	III	174 (20.2%)	38 (28.4%)	
	IV	14 (1.6%)	2 (1.5%)	
Neoadjuvant chemotherapy	No	357 (41.6%)	50 (37.6%)	0.38
	Yes	501 (58.4%)	83 (62.4%)	
Neoadjuvant radiation	No	391 (45.5%)	66 (49.3%)	0.4
	Yes	469 (54.5%)	68 (50.7%)	

* Percentages are apportioned row-wise, i.e. according to the year of diagnosis.

[+]Charlson–Deyo Comorbidity score. SD, Standard Deviation.

Table 5

Comparison of surgical outcomes after laparoscopic or laparoscopic converted to open approach.

Surgical outcome	Conversion		P-value
	No N (%)	Yes N (%)	
Margin positive rate	73 (8.5%)	7 (5.2%)	0.19
Median number of nodes examined	14.0	14.0	0.88
Median hospital length of stay (days)	10.0	11.0	0.02
Unplanned readmission rate [+]	60 (7.0%)	11 (8.2%)	0.61
Mortality rate [+]	30 (3.5%)	3 (2.2%)	0.46

[+] Event occurring within 30 days after surgery.