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Technical and perioperative outcomes of minimally invasive esophagectomy in the prone position

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Abstract
Background Minimally invasive esophagectomy (MIE) is performed through various approaches, including using video-assisted thoracoscopic surgery for mediastinal esophageal dissection. The prone technique allows for gravity-aided retraction of the lung. The aim of this study was to examine perioperative outcomes after prone MIE in relation to patient preoperative comorbidities.
Methods A retrospective cohort study from our single tertiary-care center is presented. Between January 2007 and August 2010, a total of 42 patients underwent three-field prone MIE. The majority of patients were male (37 vs. 5 female), with an average age of 68 years (range = 37–87). The diagnoses for patients who underwent MIE were 35 adenocarcinoma, four Barrett's esophagus with high-grade dysplasia, two achalasia, and one squamous cell carcinoma. Neoadjuvant chemotherapy with or without radiotherapy was administered to 16 (38 %) patients. Preoperative comorbidities were quantified using the Modified Charlson Comorbidity Index; low risk was defined as a score of 0–2 (23 patients), moderate risk 3–4 (14 patients), and high risk 5 or higher (five patients). Postoperative complications were stratified using the Clavien Classification Scale; minor complications were grades 1 and 2 and major complications were grades 3–5.
Results Median length of hospital stay was 8 days (range = 6–51) and median ICU stay was 2 days (range = 1–26). Average prone surgical time was 108 min (range = 67–198). Thirty-seven of 42 patients (88 %) were extubated on the day of operation. Postoperatively, all five high-risk patients had a complication, three of which were major. Eight of the 14 moderate-risk patients had a complication and three were major, and 17 of the 23 low-risk group had a complication with nine being major. There was a total of 15 major complications. Predominant complications were arrhythmias (15) and pneumonia (five), with four anastomotic leaks and two postoperative 30-day mortalities.
Conclusions This series supports using prone MIE. Despite a clinical pathway, including immediate extubation postoperatively, there is still a risk of pulmonary complications that appears to correlate with higher preoperative comorbidity scores.

Keywords Esophageal cancer · Esophagectomy · Minimally invasive esophagectomy

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The mainstay of treatment for malignancy of the esophagus and gastroesophageal junction has been esophagogastrectomy [1]. Techniques of minimally invasive esophagectomy (MIE) have been developed in order to reduce the morbidity and mortality associated with open esophageal resection. Initial attempts at MIE included a laparoscopic transhiatal approach, but this was abandoned by many surgeons because of the difficulty and complications of blind mediastinal dissection. Typical transthoracic approaches to MIE use either a two-field (abdomen and chest with thoracic anastomosis) or a three-field (abdomen, chest, and neck with cervical anastomosis) laparoscopic and thoracoscopic technique [2]. For the thoracic component, which is performed via video-assisted thoracoscopic surgery (VATS), the patient is placed in a lateral decubitus position, leaving the esophagus in the

lowest, most dependent part of the surgical field. To allow for adequate visualization and dissection of the esophagus, up to two experienced surgical assistants may be required to retract the lung out of the surgical field and suction blood and other pooling fluid. Recently, a prone positioning approach for thoracic esophageal dissection has been described [3–5]. This approach may be advantageous over the standard left lateral decubitus positioning as it allows for better visualization due to gravity-aided retraction of the lung as well as pooling blood and fluid away from the operative field. Herein we report our experience with three-field MIE utilizing the prone VATS technique for thoracic esophageal dissection.

Methods

Our design is an institutional review board-approved (10-005473) retrospective cohort study from a single tertiary-care referral center. Between January 2007 and August 2010, a total of 42 patients underwent three-field MIE, with the VATS portion completed in the prone position. A three-trocar technique was utilized, with no port greater than 10 mm, allowing for the use of a single surgeon and one camera operator (Fig. 1). Median follow-up was 19 months (range = 1–36 months). The data are reported as mean or median values with standard deviation or range where appropriate.

Patient factors

From the electronic medical records, demographic data, including age, sex, BMI and indication for surgery, were gathered. The use of neoadjuvant chemo- and/or radiotherapy or any other preoperative intervention such as esophageal stenting was also collected.

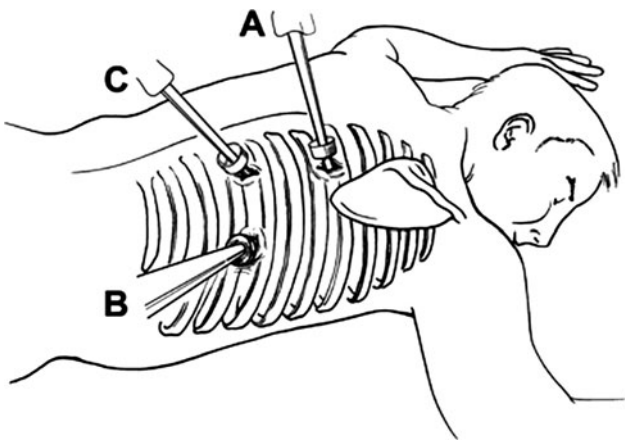

Fig. 1 Port placement for prone VATS of three-field MIE [21]

To quantify a patient's risk of morbidity and mortality preoperatively, we used a Modified Charlson Comorbidity Index to stratify a patient's individual risk [6]. Based on this, a patient was considered to be low risk if their score was 0–2, moderate risk if their score was 3–4, and high-risk if their score was 5 or higher.

Outcome variables

The operative records for all prone MIE cases were reviewed. Data points examined included operative time, estimated blood loss (EBL), type of anastomosis, and pyloric intervention. In addition, the records were reviewed to determine length of intensive care unit (ICU) stay, length of overall hospital stay (LOS), quantity of blood transfused, use and duration of chest tubes, use and duration of nasogastric tubes (NGT), postoperative days until their first swallow study, any postoperative radiologic or surgical interventions, and their postoperative course once they were discharged from the hospital.

Primary outcomes included the occurrence of a complication in the first 30 postoperative days, clarified by type (cardiac, pulmonary, thromboembolic, technical, renal, pharmacologic, delayed gastric emptying, and wound infections). Postoperative complications were also stratified using the Clavien Classification Scale [7], with minor complications being classified as grades 1 and 2 and major complications as grades 3–5 (requiring procedural intervention).

Secondary outcomes included need for anticoagulation, nutritional support [tube feeding and/or total parenteral nutrition (TPN)], or home oxygen on discharge, and any radiologic, surgical, or endoscopic intervention after discharge.

Results

Patient demographics

The majority of patients were male, with an average age of 68 ± 11 years and an average BMI of 28.2 ± 6.6 kg/m^2. Preoperative diagnoses included adenocarcinoma (35), Barrett's with high-grade dysplasia (with failure of complete endoscopic mucosal resection) (four), achalasia (two) and squamous cell carcinoma (one). Neoadjuvant chemo- and/or radiotherapy were administered to 16 (38 %) patients; one patient had a preoperative esophageal stent placed. All but one patient, who underwent neoadjuvant therapy, was stage IIB or higher. One patient had definitive treatment of a metastatic brain lesion in addition to neoadjuvant therapy prior to esophageal resection. According to the Modified Charlson Comorbidity Index, 23

Table 1 Operative time (mean)

Total operative time (positioning plus cut to close time)	431 ± 79 min
Positioning time	93 ± 23 min
Prone time	108 ± 29 min
Supine time	230 ± 58 min

Table 2 Operative time (mean) based on obesity status

	BMI ≤30 ($n = 33$)	BMI ≥30 ($n = 9$)	p value
Total operative time (min)	425 ± 69	455 ± 111	0.32
Positioning time (min)	91 ± 22	102 ± 27	0.21
Prone time (min)	108 ± 30	107 ± 25	0.93
Supine time (min)	226 ± 51	246 ± 81	0.37

patients were low risk, 14 patients were moderate risk, and five patients were high risk. Thirty of the 42 patients were either former or active smokers.

Thirty-two patients had a pyloric intervention during the MIE, including Botox injections ($n = 13$), pyloroplasty ($n = 18$), and pyloromyotomy ($n = 1$). The majority of patients (39 of 42) had common-channel stapled esophagogastrostomy with a hand-sewn closure of the anterior wall. Thirteen patients had one chest tube postoperatively and the other 29 had two chest tubes postoperatively. Two patients also had a laparoscopic left adrenalectomy performed for an adrenal mass prior to starting the MIE. Mean total operative time for all patients is given in Table 1. Table 2 displays these operative times by patient obesity status (BMI <30 vs. BMI >30), where there were no statistically significant differences. Median EBL was 180 cc (range = 20–500).

Primary and secondary outcomes

Median LOS was 8 days (range = 6–51) and the median ICU stay was 2 days (range = 1–26). Thirty-seven of the 42 patients (88 %) were extubated on the day of operation. A nasogastric tube was needed for a median of 4 days (range = 2–24), and a contrast swallow study was performed a median of 4 days (range = 3–8) postoperatively. Chest tube drainage was needed for a median of 6 days (range = 3–30).

Based on the Clavien scale for postoperative complications, 30 patients (71 %) experienced a complication. Of these, 15 (36 % of patients) were minor (grades 1–2) and 15 (36 %) were major (grades 3–5). Twelve of the 15 patients with major complications were either current or former smokers, but it was not statistically significant in smokers versus nonsmokers [12 of 30 patients (40 %) vs. 3 of 12 patients (25 %), $p = 0.48$]. There was also no significant difference in the major complication rate in obese versus nonobese patients [11 of 33 patients (33 %) vs. 4 of 9 patients (44 %), $p = 0.70$].

There were 17 low-risk patients who had at least one postoperative complication, nine of which were classified as major complications. Of these low-risk patients, seven sustained a total of eight cardiac complications and eight had 19 different pulmonary complications. There were two anastomotic leaks, one of which required further intervention (esophageal stenting).

There were eight moderate-risk patients who had complications, three of which were major. Five of these patients had a total of eight cardiac complications and two had six pulmonary complications. One patient had an anastomotic leak that required a reoperation. There was one 30-day in-hospital death, from a myocardial infarction.

Of the five high-risk patients, three had a major complication, and all patients had some postoperative complication, with three patients having three cardiac complications and three patients having a total of ten pulmonary complications. One patient developed conduit necrosis and tracheo-esophageal fistula formation that led to mortality. Table 3 summarizes all complications encountered.

Discussion

The prone MIE technique was first introduced by Cuschieri in 1994 [8]. While it has not become the preferred choice for MIE, recent studies have helped to validate it as a safe and effective alternative to the standard lateral decubitus approach [4, 5, 9]. In the standard decubitus approach, numerous ports are placed to aid in retracting the lung away from the surgical field, usually via fan retractors, requiring one or more experienced assistants. By allowing gravity to aid in retracting the lung during a prone MIE, the esophagus can be easily visualized. Fewer ports are required, reducing the number of assistants and allowing the esophagus to be dissected free of its surrounding tissues with ease.

When comparing prone MIE with the standard approach, studies have reported equivalence in blood loss, oncologic dissection, and postoperative complications but significantly shorter thoracoscopic operative times [3, 9]. Fabian et al. [9] has reported a mean operative time for prone thoracoscopic MIE of 86 min (range = 55–138) and Dapri et al. [3] has reported a time of 75 min (range = 60–90). Our thoracoscopic rates were slightly higher, with a median time of 101 min (range = 67–198). One thing not mentioned in other reports is positioning time, from supine to prone and then back to supine, which

Table 3 List of complications

Complications	Interventions
Cardiac	
Arrhythmias ($n = 15$)	Medical conversion ($n = 15$)
Myocardial infarction ($n = 3$)	Thrombolysis of clot ($n = 1$)
Bradycardic/asystolic arrest ($n = 1$)	ACLS protocol ($n = 1$)
Pulmonary	
Pneumonia ($n = 5$)	Treated with antibiotics ($n = 5$)
	Reintubated ($n = 2$), leading to tracheostomy ($n = 1$)
Aspiration ($n = 4$)	No intervention ($n = 4$)
Pneumothorax ($n = 5$)	New chest tube placed ($n = 4$)
Pleural effusion ($n = 4$)	Chest tube placed ($n = 3$)
	Chest tube, followed by operative intervention ($n = 1$)
Respiratory distress/ARDS ($n = 5$)	Reintubated (n = 5), leading to tracheostomy ($n = 1$)
Thromboembolic	
Pulmonary embolus ($n = 2$)	Anticoagulation ($n = 2$)
Deep vein thrombosis ($n = 1$, separate from PE patients)	
Technical	
Anastomotic leak ($n = 4$)	No intervention ($n = 1$)
	Operative intervention, drain positioning ($n = 1$)
	Chest tube followed by esophageal stent ($n = 1$)
Hoarseness ($n = 2$)	No direct intervention, died from necrotic conduit ($n = 1$)
	No intervention ($n = 2$)
Renal	
Acute renal failure ($n = 2$)	Hemodialysis ($n = 2$)
Urinary retention ($n = 2$)	Foley placed ($n = 2$)
Delayed gastric emptying ($n = 1$)	No intervention
Wound infection ($n = 1$, cervical wound)	Local wound care
Intrahospital TPN ($n = 4$)	
Transfusions, intraop and postop ($n = 8$)	
D/C home on	
Anticoagulation ($n = 2$)	
TPN ($n = 3$)	
Tube feeding ($n = 1$)	
Home oxygen ($n = 3$)	
Deaths within 30 days ($n = 2$):	
MI 2 days after discharge	
Necrotic stomach with TE fistula (see anastomotic leak section above)	

ARDS adult respiratory distress syndrome; *TE* thromboembolic; *ACLS* advanced cardiovascular life support

accounted for a median time of 90 min (range = 46–148), making our total operative time 426 min (range = 226–519). Considering our positioning time, our operating times are comparable to previously reported times of 375 min (range = 255–600) [9] and 377 min (range = 240–540) [3].

The majority of reports have focused on the technical aspects of the prone approach, comparing and contrasting it to the standard VATS portion of a MIE [4]. Most reports do not score and stratify patient preoperative risk factors [5, 9, 10], which could have helped support the argument that the use of minimal access techniques is helpful in reducing complications in those high-risk patient groups. There have been reports that used preoperative risk stratification, but most of them focused on open esophagectomy techniques [1, 11–16]. The only study that analyzed risk-stratified outcomes of MIE used data from a national administrative database [17], and it showed similar mortality and length-of-stay outcomes when MIE was compared to the open approach, but it supported the position that large-scale randomized control trials would be needed to confirm their results.

For appropriate risk stratification, we used to the Charlson Comorbidity Index (CCI). It was developed in 1987 and assessed 19 medical conditions that appear to significantly affect patient survival. Each condition was given a weighted number, and it was shown that with an increase in the comorbidity-specific index score there was a similar increase in mortality risk [18]. While at first the CCI was solely used on medical patients, studies showed that it also correlated with a higher surgical risk and was better at predicting risk then examining individual risk factors [6]. The CCI has also been used to specifically evaluate patients undergoing open esophagectomy, with the finding that a higher score is associated with increased mortality after open esophagectomy [1]. We found that the CCI was helpful in classifying patients as low, moderate, and high risk, allowing for better evaluation and correlation of postoperative complications. By risk stratifying our patient population we are able to show that the higher-risk groups undergoing prone MIE are more likely to develop major postoperative complications.

All the patients who fell into the high-risk stratification category developed a postoperative complication, with the majority developing a major complication. The major complications in this high-risk group were, for the most part, pulmonary, with patients usually having more than one pulmonary complication during their hospital stay; these included pleural effusions, aspiration, respiratory distress, and reintubation. This high-risk group was also more likely to receive blood products, either intraoperatively and/or postoperatively. Finally, all mortality was seen in the higher-risk groups.

Another potential concern for postoperative complications is obesity. While a higher BMI has been examined as a potential predictor of complications after major surgery, it is not one of the measures examined in the CCI. Furthermore, studies have reported that obesity is not associated with an increase in major postoperative complications in MIE patients [13, 19]. This is important when evaluating our patient population, considering that only 30 % of the patients who underwent prone MIE were had a BMI <25. While there is no published report associating obesity with an increased complication rate after MIE, studies have reported longer MIE operative times related to obesity [13]. We report that operating time and positioning time were not significantly different between obese and nonobese patients.

Because an overwhelming majority of our MIE patients had a smoking history, we did not note a significant association between smoking and complications. Interestingly, studies have reported that tobacco use or abuse does not have an independent effect on the postoperative course of the open esophagectomy patient [11, 20].

Conclusions

This reported series supports the use of the prone MIE approach. Despite its facilitation of the thoracic portion of an esophagectomy, cardiopulmonary complications are still a common finding, although these complications are more often found in the high-risk patient population.

Disclosures Drs. Goldberg, Bowers, Parker, Stauffer, Asbun, and Smith have no conflicts of interest or financial ties to disclose.

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