EURASIAN JOURNAL OF CHEMICAL, MEDICINAL AND PETROLEUM RESEARCH

Volume 5, Issue 1

Eurasian Journal of Chemical, Medicinal and Petroleum Research

Journal homepage: https://www.ejcmpr.com/

DOI: https://zenodo.org/records/17202426

Comparative Outcomes of Minimally Invasive Versus Open Esophagostomy for Distal Esophageal Cancer: A Retrospective Cohort Study from a Tertiary Referral Center

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Article info
Received: 18.08.2025
Accepted: 24.09.2025
Available Online: 25.09.2025
Checked for Plagiarism: Yes

Keywords: Esophageal cancer, Minimally invasive esophagostomy (MIE), Open esophagostomy (OE), Surgical outcomes, Chylothorax

A B S T R A C T

Introduction: Esophageal cancer is a leading cause of cancer-related mortality globally. While open esophagostomy (OE) remains a standard treatment, it is associated with considerable morbidity and mortality. Minimally invasive esophagostomy (MIE) has emerged as an alternative with potentially fewer complications and faster recovery. This study aimed to compare the outcomes and complications of MIE versus OE in patients with distal esophageal cancer.

Materials and Methods: This retrospective cohort study included 196 patients with distal esophageal cancer treated between 2015 and 2021 at two tertiary hospitals in Tehran. Patients were equally divided into MIE (n=98) and OE (n=98) groups. Preoperative, intraoperative, and postoperative variables including surgical duration, pain intensity, intraoperative blood loss, transfusion requirements, hospital stay, and complication rates were collected and analyzed using SPSS version 23. Appropriate statistical tests were applied with a significance level set at $p<0.05$.

Results: The mean duration of surgery was significantly shorter in the MIE group compared to the OE group (280.71±44.83 vs. 425.36±51.69 minutes, $p<0.001$). MIE patients experienced significantly less intraoperative blood loss (297.14 ± 89.29 vs. 503.57 ±122.02 mL, $p<0.001$), required fewer blood transfusions (2.14±0.52 vs. 2.64±0.90 units, $p<0.001$), and had a shorter hospital stay (14.14± 3.27 vs. 18.64±4.31 days, $p<0.001$). Postoperative pain was also lower in the MIE group (2.86±1.36 vs. 3.43±2.48, $p=0.048$). However, the number of lymph nodes dissected was significantly higher in the OE group (18.50±3.48 vs. 9.57±3.79, $p<0.001$), and the incidence of chylothorax was greater in the MIE group (7 vs. 1 cases, $p=0.030$). There was no statistically significant difference in tracheal injury between the groups ($p=0.054$).

Conclusion: Minimally invasive esophagostomy offers several clinical benefits over open surgery, including reduced blood loss, lower postoperative pain, shorter operative time, and decreased hospital stay. However, it is associated with a higher incidence of chylothorax and a lower lymph node yield, possibly due to the learning curve and technical nuances. These findings support the use of MIE in selected patients, emphasizing the need for continued refinement of technique and surgical expertise to optimize outcomes.

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Introduction

Over the past two decades, the global incidence of esophageal cancer has increased by approximately 50%. Each year, an estimated 482,300 individuals are diagnosed with esophageal cancer, and 84.3% of these patients die due to the disease worldwide(1, 2). Esophageal cancer is considered the fifth most common malignancy in developed countries(3).

Currently, surgery remains the primary treatment for patients with esophageal cancer. The surgical procedure, known as esophagostomy, involves the removal of part or all of the esophagus and can be performed using various techniques. Open esophagostomy (OE), performed via transthoracic or trans hiatal approaches, has traditionally been regarded as an effective method for treating esophageal cancer. However, it is associated with a range of complications, including cardiac arrhythmias, pneumonia, and pleural effusion. Furthermore, extended postoperative hospitalization, significant intraoperative bleeding, and severe postoperative pain are among the major concerns observed in patients undergoing open esophagostomy. In addition, this conventional approach is associated with considerable in-hospital mortality, reported to range from 1.2% to 8.8% across different studies(4, 5).

Compared to OE, minimally invasive esophagostomy (MIE) has gained increasing attention in recent years due to its comparable oncologic efficacy, reduced complication rates, faster postoperative recovery, and shorter hospital stay. Given the extensive thoracic and abdominal incisions and the invasive nature of traditional surgery for esophageal cancer, minimally invasive techniques have become increasingly favored among surgeons(6).

These approaches, introduced approximately two decades ago, are mainly categorized into two techniques:

- ✓ Laparoscopic trans hiatal esophagostomy with cervical incision and cervical esophagogastric anastomosis
- ✓ Laparoscopic gastric mobilization combined with thoracoscopic esophageal dissection, followed by anastomosis in the thorax or neck

Numerous studies and meta-analyses have been conducted to evaluate the efficacy of these techniques. Some have clearly demonstrated the advantages of minimally invasive approaches over open surgery, such as faster wound healing and fewer pulmonary complications in MIE. The enhanced visual field in minimally invasive surgery allows for more precise dissection within the mediastinum and abdominal cavity, along with reduced intraoperative blood loss(7, 8).

However, the findings of some studies remain inconsistent, and the true benefits of minimally invasive techniques in reducing postoperative complications particularly mortality compared to open surgery are still under debate (2, 9).

Therefore, the present study aims to evaluate the outcomes and complications of minimally invasive versus open esophagostomy in patients with esophageal cancer treated between 2015 and 2021.

Methods & Materials

Study Implementation

This study was conducted as a retrospective cohort. The study population comprised 194 patients diagnosed with distal esophageal cancer who underwent treatment at the Cancer Institute and Amir Alam Hospital, Tehran, between 2015 and 2021. All patients were evaluated preoperatively using thoracic and abdominal computed tomography (CT) scans and liver function tests to assess for metastasis. Surgical contraindications included distant metastasis, metastatic cervical lymphadenopathy, bulky celiac lymphadenopathy, and evidence of invasion into mediastinal organs.

Patient selection was performed purposefully from two groups: those undergoing open esophagostomy and those undergoing minimally invasive esophagostomy. A minimum of 97 patients were included in each group, and the required clinical data were extracted from medical records and patient files.

Data Collection Tool

Data were collected using a researcher-designed checklist, which included patient age, sex, tumor staging, duration of surgery, postoperative pain intensity, and postoperative complications including anesthesia-related issues, wound and abdominal infections, pneumonia, deep vein thrombosis (DVT), cardiopulmonary complications, organ failure, peritonitis, cervical anastomotic leak, chylothorax, hem thorax, pulmonary embolism, fistula, mediastinitis, chyle leak, intraoperative blood loss, transfused blood products, and length of Intensive Care Unit (ICU) and hospital stay. All data were obtained from patient records in both groups.

Sample Size Calculation

The sample size was calculated based on the study by Zingg et al. (10) assuming p_1=0.23 and p_2=0.34 for surgical morbidity between the two groups, with a clinically meaningful difference of 20%. Considering a study power of 80% and a significance level of 0.05, the minimum required sample size was estimated to be 98 patients per group, totaling 196 patients.

Inclusion and Exclusion Criteria

Inclusion criteria: All patients who were candidates for surgery and had cardiovascular fitness, tumor size less than 4 Centimeter (cm), and mucosal involvement of the esophagus less than 6 cm, with no preoperative evidence of invasion into major vessels or trachea, or unrespectable mediastinal lymphadenopathy.

Exclusion criteria: Patients with intraoperative findings of ascites, liver or lung metastases, peritoneal seeding, involvement of para-aortic or bulky sub carinal and celiac trunk lymph nodes, or cervical esophageal extension.

Surgical Procedures

Patients in the open surgery group underwent either trans hiatal or transthoracic esophagostomy (McKeon approach), based on tumor location and patient anatomy. Tumors close to the trachea or carina were managed via transthoracic esophagostomy to avoid mediastinal injury. Tumors involving the cervical or lower third of the esophagus, or cardia, were treated with trans hiatal esophagostomy.

In the minimally invasive group, trans hiatal laparoscopic esophagostomy was performed. The initial port was placed above the umbilicus using an open technique. A 10 Millimeters(mm) camera was introduced to assess peritoneal metastasis and adhesions. If operability was confirmed, additional ports were placed bilaterally 10 cm below the costal margin and one on the right side for liver retraction. The stomach was mobilized using a Ligasure device, and the left gastric artery was divided using an Endo Gastrointestinal(GI) stapler. The esophagus was transected using 3–4 Endo Gastrointestinal Anastomosis (GIA) staplers (60 mm), approximately 5 cm above the cardia. Frozen sections were sent to confirm negative margins.

Gastric pull-up and cervical anastomosis were completed under direct laparoscopic and open guidance via a cervical incision. In the thoracoscopic approach, patients were positioned in a left lateral decubitus and flexed posture. Ports were placed below the scapula, in the mid-axillary line, and above the diaphragm. A 12-mm assistant port and a 5-mm port were also placed as needed.

Thoracic dissection was initiated inferiorly and proceeded superiorly, with division of the inferior pulmonary ligament and Penrose-assisted esophageal retraction. Dissection of vascular and lymphatic branches was performed using the Enseal device, taking care to preserve the recurrent laryngeal nerve (RLN). Esophageal division was completed 5 cm above the tumor in MIE or just below the subclavian vessels in McKeon MIE.

In cases of End to End Anastomosis (EEA), the esophageal stump was exteriorized through the left working port, and the anvil was secured using EndoStitch. Intercostal nerve blocks were performed with liposomal bupivacaine; epidural catheters were rarely used. Operation time was recorded in both groups for comparison.

Postoperative Management and Outcomes Assessment

In both groups, epidural catheters were inserted for postoperative pain control. Patients were positioned supine with legs apart following general anesthesia. Postoperative pain was assessed using the Visual Analog Scale (VAS) score.

Patients were also monitored and compared for anesthesia-related complications, wound and abdominal infections, pneumonia, DVT, cardiopulmonary events, organ failure, peritonitis, cervical anastomotic leak, chylothorax, hem thorax, pulmonary embolism, fistula, mediastinitis, chyle leak, intraoperative blood loss, transfusion volume, ICU and hospital length of stay. Surgical outcomes were further compared based on age, sex, and tumor stage.

Statistical Analysis

All collected data were entered into Statistical Package for the Social Sciences(SPSS) software version 23 and analyzed using appropriate statistical tests to assess the significance of differences between the two surgical groups.

Results

In this study, a total of 196 patients were evaluated, with 98 patients in the minimally invasive surgery group and 98 in the open surgery group. The mean age of patients in the minimally invasive group was 57.90 ± 11.196 years (range: 30–70 years), while in the open surgery group it was 61.21 ± 5.900 years (range: 51–74 years). According to the results of Levene's test, the variances between the two groups were unequal. Based on the P-value of 0.010 obtained from the t-test (assuming unequal variances), the difference in age between the two groups was not statistically significant.

Regarding tracheal injury, 6 patients in the minimally invasive group and 1 patient in the open surgery group experienced this complication. Based on the statistical analysis, the difference was not statistically significant (P-value =0.054), indicating no significant difference in tracheal membrane injury between the two surgical approaches.

In contrast, injury to the thoracic duct (chylothorax) was observed in 7 patients in the minimally invasive group and 1 patient in the open surgery group. According to the Chi-square test results, this difference was statistically significant (P-value = 0.030), indicating a higher incidence of thoracic duct

injury in the minimally invasive group compared to the open surgery group. (Table-1)

Table1. Comparison of chylothorax between two surgical methods

Surgical procedure	Chylothorax	P-Value
MIE	7	0.03
OE	1	

The mean number of lymph nodes removed in the minimally invasive group was 9.57±3.794, while in the open surgery group it was 18.50±3.477. According to the results of the Levene's test, the variances of the two groups were equal. Based on the P-value <0.001 obtained from the t-test assuming equal variances, the number of lymph nodes removed in the open surgery group was approximately twice that of the minimally invasive group, indicating significantly more extensive lymph node dissection in the open approach. (Table-2)

Table2. Comparison of lymph node dissection between two surgical methods

Lymph node dissection	Mean and standard deviation	P-Value
MIE	9.57 ± 3.794	<0.001
OE	18.5 ± 3.477	

The mean pain intensity in the open surgery group was 3.43±2.483, compared to 2.86±1.362 in the minimally invasive group. According to the results of the Levene's test, the variances of the two groups were not equal. Given the P-value=0.048 obtained from the t-test assuming unequal variances, pain intensity was significantly higher in the open surgery group. (Table-3)

Table3. Comparison of pain intensity between two surgical methods

Pain	Mean and standard deviation	P-Value
MIE	1.362 ± 2.86	0.048
OE	3.43 ± 2.483	

The mean duration of surgery in the minimally invasive group was 280.71±44.825 minutes, while in the open surgery group it was 425.36±51.689 minutes. Based on Levene's test, the variances of the two groups were equal. According to the P-value < 0.001 obtained from the t-test assuming equal variances, the duration of surgery was significantly longer in the open surgery group. (Table-4)

Table4. Comparison of duration of surgery of two surgical methods

Duration of surgery	Mean and standard deviation	P-Value
MIE	280.71 ± 44.825	<0.001
OE	425.36 ± 51.689	

The mean intraoperative blood loss in the minimally invasive group was 297.14±89.293 mL, compared to 503.57±122.021 mL in the open surgery group. According to the results of the Levene's test, the variances of the two groups were not equal. Based on the P-value < 0.001 from the t-test assuming unequal variances, intraoperative blood loss was significantly higher in the open surgery group. (Table-5)

Table5. Comparison of blood loss of two surgical methods

Surgical blood loss	Mean and standard deviation in millimeter	P-Value
MIE	297.14 ± 89.293	<0.001
OE	503.57 ± 122.021	

The mean amount of transfused blood products (in terms of cell packs) in the open surgery group was 2.64±0.900, while in the minimally invasive group it was 2.14±0.518. According to Levene's test, the

variances of the two groups were not equal. Based on the P-value < 0.001 from the t-test assuming unequal variances, the amount of transfused blood products was significantly higher in the open surgery group. (Table-6)

Table6. Comparison of the amount of packed cell transfused between two surgical methods

Packed cell transfused	Mean and standard deviation	P-Value
MIE	2.14 ± 0.518	<0.001
OE	0.9 ± 2.64	

The mean length of hospital stay after surgery was 14.14±3.265 days in the minimally invasive group and 18.64 ± 4.308 days in the open surgery group. According to the Levene's test results, the variances of the two groups were not equal. Based on the P-value <0.001 from the t-test assuming unequal variances, the length of hospital stay after surgery was significantly longer in the open surgery group. (Table-7)

Table7. Comparison of the hospital stay between two surgical methods

Hospital stay	Mean and standard deviation	P-Value
MIE	14.14 ± 3.265	<0.001
OE	4.308 ± 18.64	

Discussion

In the study by Depaula et al. in 1995, where laparoscopic esophagostomy was performed for the first time, it was shown that intraoperative blood loss was lower with this technique(11).

The study by Scheepers et al. in 2008, conducted on 75 patients at Vrije University Medical Center (60 patients with lower esophageal or gastroesophageal junction cancer, and 15 with mid-esophageal cancer), demonstrated that better visualization in the minimally invasive approach led to reduced intraoperative bleeding(12).

In a 2005 study by Shmel et al. at the Cleveland Clinic in Florida on 19 patients (3 with adenocarcinoma and 16 with SCC) undergoing laparoscopic esophagostomy, reduced blood loss was highlighted as a main benefit of this method. In that study, the average blood loss ranged from 220 to 500 cc(13).

Similarly, in the present study, the mean±standard deviation of intraoperative blood loss in the minimally invasive group was 297.14±89.293 mL, compared to 503.57±122.021 mL in the open surgery group. Therefore, blood loss was significantly lower in the minimally invasive group. The study by Butler et al. in 2011 also demonstrated that the length of hospital stay after surgery was reduced with minimally invasive approaches(14).

In the study by BeheshtyRouy et al., laparoscopic trans hiatal esophagostomy was performed on 11 patients with distal esophageal cancer at Tabriz University. The reported hospital stay was 10.55 ± 4.80 days(7).

In the current study, the mean hospital stay was 14.14±3.265 days in the minimally invasive group and 18.64±4.308 days in the open group. Thus, the length of hospital stay was significantly longer in the open approach, consistent with the aforementioned studies.

The study by Kristo et al. in 2018 reported no significant difference in operative time between open and minimally invasive approaches. However, in contrast to Kristo's findings, the present study showed that operative time was significantly longer in the open surgery group (425.36±51.689 minutes vs. 280.71±44.825 minutes)(15).

Regarding tracheal injury, no significant difference was observed between the two groups in this study. However, thoracic duct injury (chylothorax) occurred significantly more often in the minimally invasive group. Notably, in the final year of the study, the use of contrast agent injection to visualize the duct led to a marked reduction in this complication in the thoracoscopic group.

The 2011 study by Butler et al. also showed that postoperative pain was reduced in minimally invasive surgery. In the present study, pain intensity was significantly higher in the open group compared to the minimally invasive group (3.43±2.483 vs. 2.86±1.362)(14).

The 2005 study by Shmel et al. suggested that due to better visualization, lymph node dissection was more extensive in the minimally invasive approach. (12) However, contrary to that, the current study found greater lymph node dissection in the open group (18.50±3.477 vs. 9.57±3.794).

This discrepancy in the number of lymph nodes dissected may reflect differences in surgical experience, learning curve, or technical limitations associated with the minimally invasive approach, especially in the early years of the study. However, toward the end of the study period, with growing expertise and optimization of the technique, the number of lymph nodes retrieved in minimally invasive cases began to approach those of the open

group. This finding suggests that surgical proficiency plays a critical role in achieving oncologic adequacy with MIE.

Despite the lower extent of lymphadenectomy in the minimally invasive group, the approach demonstrated several important advantages. The significantly lower blood loss and transfusion requirement in MIE cases underscore the benefit of reduced surgical trauma and enhanced hemostatic control due to improved magnified visualization. Furthermore, shorter hospital stays and reduced postoperative pain in the MIE group are consistent with faster recovery, decreased morbidity, and potentially lower healthcare costs.

One of the unexpected findings of this study was the higher incidence of chylothorax in the MIE group. Although this may reflect the technical challenges of thoracic duct preservation in a minimally invasive setting, the marked reduction in chylothorax observed after the implementation of intraoperative contrast injection emphasizes the importance of technique refinement and preventative strategies. These adaptations may mitigate such complications as surgeons gain experience.

The lack of a statistically significant difference in tracheal injuries between the two approaches may suggest that, while rare, this complication is more likely related to tumor location and invasiveness than to the surgical approach itself.

Another point worth noting is the operative time. Contrary to several prior studies where MIE was associated with longer operative durations due to its technical complexity, this study showed a significantly longer operative time in the open group. This may reflect increased tissue handling, higher bleeding requiring control, and potentially more complex lymph node dissection in the open approach.

Clinical Implications

The results of this study support the adoption of minimally invasive esophagostomy in appropriately selected patients, given its association with reduced blood loss, shorter hospital stays, and decreased postoperative pain. However, attention should be paid to the technical learning curve, particularly in achieving adequate lymphadenectomy and avoiding specific complications such as chylothorax.

Limitations

This study has several limitations. First, it was conducted at 2 centers, and variations in surgeon experience across different centers may influence outcomes. Second, although the number of patients in each group was equal, selection bias may have affected the assignment of patients to surgical groups. Third, long-term oncologic outcomes such as recurrence and survival were not evaluated in this study and should be addressed in future research.

Conclusion

Minimally invasive esophagostomy was associated with significantly lower intraoperative blood loss, shorter hospital stays, less postoperative pain, and reduced need for transfusions compared to open esophagostomy. While lymph node dissection was greater in the open group, improvements were noted in the minimally invasive group over time. With adequate training and careful technique, minimally invasive approaches can provide favorable outcomes and may represent the preferred option for many patients undergoing esophageal cancer surgery.

Declarations

Abbreviations:

- ✓ Open esophagostomy (OE).
- ✓ Minimally invasive esophagostomy (MIE).
- ✓ Computed tomography (CT).
- ✓ Deep vein thrombosis (DVT).
- ✓ Intensive Care Unit (ICU).
- ✓ Centimeter (cm).
- ✓ Millimeters(mm).
- ✓ Gastrointestinal(GI).
- ✓ Gastrointestinal Anastomosis (GIA).
- ✓ Recurrent laryngeal nerve (RLN).
- ✓ End to End Anastomosis (EEA).
- ✓ Visual Analog Scale (VAS).
- ✓ Statistical Package for the Social Sciences(SPSS).

Ethics approval and consent to participate

The implementation of this study and its related details were approved by the Ethics Committee in Research of Tehran University of Medical Sciences. The principles of the Helsinki Declaration were fully observed in this study. The data obtained from patients has remained confidential and is used solely for scientific purposes. The principles of article publication and the rights of the researchers have been observed in accordance with authorship guidelines. Participation in this study did not deprive patients of receiving standard treatment. No additional costs were charged to patients for the examinations conducted in this study. Informed consent to participate was obtained from all of the participants in the study

Consent for publication

not applicable.

Availability of data and materials

All the information extracted in this study is available in the medical records department of Amir Alam Hospital and Imam Khomeini Cancer Institute

in Tehran and will be provided by Co-respond author if access is required for a reasonable reason.

Competing Interests
The authors declare no competing interest regarding the publication of this article.

Funding
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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- ✓ Ali Asghar Yazdani: Data collection & Analysis.
- ✓ Hossein Gandomkar: Patients care & Surgeries & 2nd co-responding author.
- ✓ Habibollah Mahmoodzadeh:Patients care & Surgeries.
- ✓ Zahra Moghimi: Manuscript writing & data collection.
- ✓ Ehsan Sobhanian: Manuscript writing & data collection & 1st co-responding author.

Acknowledgement
We sincerely thank Imam Khomeini Hospital and Amir Alam staff, study participants, and the ethics committee for their support. Special appreciation to our colleagues, mentors, and loved ones for their invaluable guidance, encouragement, and contributions to this research.

Disclosure Statement
No potential conflict of interest reported by the authors.

Authors' Contributions
All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

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