

Hybrid thoracoscopic esophagectomy: the first promising results from a single-center retrospective study in Greek population

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Abstract

Introduction: The application of minimally invasive surgery, and in particular the hybrid thoracoscopic approach, in esophageal cancer treatment is expected to decrease postoperative morbidity. The question is whether the thoracoscopic esophagectomy is safe and oncologically efficient when performed in mid-volume centers in small countries such as Greece, where the incidence of esophageal cancer is low.

Material and Methods: We conducted a retrospective analysis that included 75 patients who underwent esophagectomy due to esophageal cancer from 1st January 2017 until 31st December 2023 in our department. Demographic and tumor characteristics, surgical procedures, resected lymph nodes, postoperative morbidity, and mortality are the main factors studied.

Results: Eighty-four percent of the patients were male, while 86.7 % of the lesions were classified as adenocarcinoma. In the transhiatal group, major postoperative complications were significantly lower ($p = 0.039$). When comparing the hybrid thoracoscopic esophagectomy to the conventional open, no statistically significant difference was found regarding the length of hospital stay ($p = 0.480$), the major complications ($p = 0.129$), the mortality ($p = 1$), and the total number of lymph nodes resected ($p = 0.169$). However, further subgroup analysis indicated that the thoracoscopic McKeown esophagectomy was associated with significantly fewer severe postoperative complications than the open ($p = 0.004$).

Conclusions: The thoracoscopic esophagectomy is safe and oncologically efficient compared to the conventional open approach, even in mid-volume centers. The significantly fewer major postoperative complications concerning the three-field esophagectomy that favor the hybrid approach are encouraging for the future. The transhiatal approach remains a decent alternative for patients with severe comorbidities. HIPPOKRATIA 2024, 28 (4):150-157.

Keywords: Esophageal cancer, thoracoscopy, minimally invasive surgery, hybrid esophagectomy

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Introduction

Esophageal cancer is the 7th most common cancer type worldwide and the 6th leading cause of death related to cancer^{1,2}. However, in Greece, the incidence of esophageal carcinoma is relatively low, as it suggests the 24th type of cancer according to the World Health Organization and the International Agency for Research on Cancer, with 247 new cases diagnosed in 2020. When symptoms such as dysphagia present, the disease is usually locally advanced and accompanied by lymphatic spread. A significant proportion of patients are considered not suitable for surgical treatment because of metastatic disease or poor performance status. In contrast, endoscopic treatment has been suggested as a first-line treatment for early-stage tumors. As a result, the number of patients suitable for surgical treatment is relatively low.

On the other hand, its prevalence has an increasing tendency because of the increasing number of pathological conditions such as gastroesophageal reflux disease (GERD), obesity, and Barrett's dysplasia³, a direct out-

come of the modern lifestyle. Esophagectomy is a procedure associated with increased morbidity and mortality. Minimally invasive approaches, including various combinations, from hybrid to totally thoraco-laparoscopic or robotic, have been proposed to improve the postoperative course. This study investigated whether hybrid esophagectomy, combining thoracoscopy and laparotomy, is feasible, safe, and oncologically adequate compared to the conventional open approach.

Material and Methods

We conducted a retrospective cohort study that included all patients who underwent esophagectomy for esophageal or gastroesophageal junction cancer (GEJ, Siewert I, and II) in our surgical department from 1st January 2017 until 31st December 2023. Patients with progressive disease who received palliative treatment with feeding gastrostomy and patients who underwent esophagectomy because of esophageal perforation were excluded from this study. During their hospitalization, patients

received the standards of care according to institutional approved guidelines, and we obtained retrospective approval from the institution's Scientific and Ethics Committee regarding the retrospective collection and usage of the demographic and clinical data.

Until August 2021, all the procedures were performed in the traditional way, with an open approach. From August 2021 onwards, after appropriate training was obtained, the thoracoscopic approach became the standard of care for most cases. No randomization was performed. For patients with serious comorbidities, the transhiatal approach remained an option. Open thoracotomy was selected for the patients with previous thoracic surgery because of the presence of adhesions. Conversion to open was inevitable in three cases, either because of radiation-induced excessive fibrosis or because of adhesions probably due to previous pulmonary infection. A single surgeon performed all the procedures.

Age, sex, tumor location, American Society of Anesthesiology (ASA) score, neoadjuvant chemotherapy (NAC), preoperative radiation, type of operation, surgical approach, and total number of lymph nodes harvested are some factors analyzed in this study. We estimated the short-term outcomes, such as length of hospital stay (LOS), postoperative complications, and mortality. We also evaluated the long-term outcomes, including overall survival (OS) and disease-free survival (DFS).

Initially, we divided the patients into three main groups based on the surgical approach. Group 1 included the conventional open approach, which consists of laparotomy and thoracotomy with or without cervical incision; Group 2 included the hybrid thoracoscopic approach consisting of thoracoscopy and laparotomy with or without cervical incision; and Group 3 included the transhiatal approach. A statistical analysis was performed to identify any significant differences among groups. Further subgroup analysis was applied to investigate similar outcomes or even possible superiority of the hybrid approach compared to the traditional open, overall, and afterward separately for Ivor-Lewis and McKeown esophagectomy.

We used the Clavien Dindo classification system for

the postoperative complications, defining those as major complications equal to grade IIIb and above. The IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA) was used for data analysis. We used the independent samples t-test for continuous variables, the Mann-Whitney test for non-parametric variables, the ANOVA test to estimate statistical significance among multiple groups for continuous variables, and the Kruskal-Wallis test when appropriate. We used Pearson's chi-square for the categorical variables and Fisher's exact test when appropriate. We set the level of statistical significance to 0.05 and performed Kaplan Meier with log-rank analysis for the survival analysis.

Results

Seventy-five patients were included in this study, with a mean age of 64.17 (range 39-81) years, and the majority (70.6 %) were between 50 and 70 years of age. Eighty-four percent (63/75) of the patients were male. Table 1 presents patients' demographic characteristics. We observed no significant differences concerning age and sex among the groups.

The tumor was located on the distal third of the esophagus or the esophagogastric junction in 32 % (24/75) and 56.1 % (42/75) of the patients, respectively. Esophagectomy was primarily performed in patients with T1-2 N0 M0 stage, while 61.3 % (46/75) of the patients received NAC due to higher T status or presence of lymph node involvement. In addition, 13.3 % (10/75) received radiotherapy prior to surgery. Regarding tumor histopathology, 86.7 % (65/75) of the lesions were classified as adenocarcinoma, whereas 13.3% (10/75) of the tumors as squamous-cell carcinomas, as shown in Table 2, demonstrating the increasing incidence of esophageal adenocarcinoma in the Western developed countries, as a direct result of GERD and obesity. No particular differences regarding tumor location, tumor biology, and the administration of any neoadjuvant therapy were found among the groups.

Ivor Lewis esophagectomy was performed in 45.3 % of the patients, followed by McKeown (32 %), and transhiatal esophagectomy (22.7 %) (Table 3). A hybrid

Table 1: Demographic and clinical characteristics of the 75 patients who underwent esophagectomy due to esophageal cancer divided according to the surgical approach (open, hybrid, transhiatal).

	Total cohort (n =75)	Open (n =30)	Hybrid (n =28)	Transhiatal (n =17)	P	Open vs Hybrid
Age	64.17 ± 9.8 (39-81)				0.825	0.377
<50	4 (5.3)	2 (2.65)	2 (2.65)	0		
50-70	53 (70.6)	21 (28)	20 (26.6)	12 (16)	0.992	0.904
>70	18 (24.1)	7 (9.3)	6 (8)	5 (6.67)	0.826	0.862
Gender					0.948	0.802
Male	63 (84)	25 (33.3)	24 (32)	14 (18.6)		
Female	12 (16)	5 (6.7)	4 (5.3)	3 (4)		
ASA Score					0.007	
ASA I	12 (16)	5 (6.7)	7 (9.3)	0		0.433
ASA II	50 (66.7)	20 (26.6)	21 (28)	9 (12)	0.088	0.485
ASA III	13 (17.3)	5 (6.7)	0	8 (10.6)		

Value for age is given as mean ± standard deviation and range in brackets and for all other variables as number and percentage in brackets. ASA: American Society of Anesthesiology, n =number.

Table 2: Tumor characteristics and need for preoperative treatment regarding the 75 patients who underwent esophagectomy due to esophageal cancer divided according to the surgical approach (open, hybrid, transhiatal).

	Total cohort (n =75)	Open (n =30)	Hybrid (n =28)	Transhiatal (n =17)	P	Open vs Hybrid
Tumor location					0.196	0.267
Upper esophagus	1 (1.3)	0	0	1 (1.3)		
Middle esophagus	8 (10.6)	5 (6.7)	3 (4)	0		0.511
Distal esophagus	24 (32)	12 (16)	6 (8)	6 (8)	0.300	0.126
Gastroesophageal junction	42 (56.1)	13 (17.3)	19 (25.3)	10 (13.3)	0.164	0.060
Tumor pathology					0.569	0.802
Squamous cell carcinoma	10 (13.3)	5 (6.7)	4 (5.3)	1 (1.3)		
Adenocarcinoma	65(86.7)	25 (33.3)	24 (32)	16 (21.3)		
Neoadjuvant therapy					0.597	0.533
Yes	46 (61.3)	18 (24)	19 (25.3)	9 (12)		
No	29 (38.7)	12 (16)	9 (12)	8 (10.6)		
Radiotherapy					0.233	0.634
Yes	10 (13.3)	4 (5.3)	5 (6.7)	1 (1.3)		
No	65 (86.7)	26 (34.6)	23 (30.6)	16 (21.3)		

Values are given as number and percentage in brackets. n =number.

Table 3: Type of surgery and short-term outcomes for the 75 patients who underwent esophagectomy due to esophageal cancer divided according to the surgical approach (open, hybrid, transhiatal).

	Total cohort (n =75)	Open (n =30)	Hybrid (n =28)	Transhiatal (n =17)	P	Open vs Hybrid
Esophagectomy						
Ivor Lewis	34 (45.3)	18 (24)	16 (21.3)			0.840
McKeown	24 (32)	12 (16)	12 (16)			0.295
Conduit for esophageal replacement						
Stomach	68 (90.6)	25	27	16	0.197	0.101
Colon	6 (8.1)	4	1	1	0.366	0.185
Jejunum	1 (1.3)	1	0	0		
LOS (days)	18.5 ± 11.7	18.5 ± 12.4	19.7 ± 10.5	17.9 ± 12.4	0.608	0.480
Total number of lymph nodes	26.7 ± 15.7	26.3 ± 12.9	33.8 ± 17.9	26.7 ± 15.6	0.721	0.169
Number of positive lymph nodes	2.25 ± 2.6	2.23 ± 2.63	2.33 ± 2.39	2.11 ± 1.07	0.550	0.934

Values are given as mean ± standard deviation and range in brackets or number and percentage in brackets. LOS: length of stay, n =number.

approach, which consists of laparotomy followed by thoracoscopy in the left lateral position in the case of Ivor Lewis esophagectomy, or right thoracoscopy followed by laparotomy with cervical anastomosis in the case of three-field esophagectomy was performed in a total of 28 patients, while three patients underwent laparoscopic transhiatal esophagectomy with cervical anastomosis. Gastric conduit was used for esophageal replacement in 90.6 % (68/75) of the cases, followed by colon and jejunum in 8.1 % (6/75) and 1.3 % (1/75) respectively, in which cases stomach was not an option due to prior operations. No significant differences were identified among the groups regarding the choice of the conduit.

Regarding the overall complication rate, 22.67 % of the patients (17/75) developed major postoperative complications, while the mortality was 8 % (6/75) (Table 4). No significant differences were found among groups regarding overall complication rates (p =0.222) and mortality, suggesting that the hybrid approach is at least as safe as the conventional one. However, patients submitted to

the hybrid thoracoscopic esophagectomy developed significantly less major postoperative complication rates in comparison to the open group (p =0.039), indicating a possible superiority of this method. Only one patient in the thoracoscopic group passed away because of necrosis of the gastric conduit.

Specifically, eight patients (10.6 %) developed anastomotic leak, which was managed conservatively or endoscopically with a stent placement, whereas necrosis of the gastric conduit occurred in three cases (4 %) who were urgently reoperated. Airway injury (2/75), strongly related to the double-lumen endobronchial tubes, was recognized intraoperatively in two patients; even though it was immediately repaired with the pericardial patch, both patients passed away in the Intensive Care Unit (ICU) in the early postoperative period. In addition, seven patients (9.3 %) developed respiratory failure requiring intubation and admission to the ICU, four patients (5.3 %) ended up with tracheostomy, while seven patients (9.3 %) developed pneumonia managed in the surgical

ward. Cervical anastomosis was associated with significantly higher anastomosis-related complications such as leakage, conduit necrosis, and stenosis, in comparison with the intrathoracic (Fisher's exact test =0.015, odds ratio (OR) =0.091, 95 % confidence interval (CI): 0.011-0.775, whereas the surgical approach did not consist an important factor (Table 5). The type of conduit was not associated with the possibility of an anastomotic leak (p =0.138). No recurrent laryngeal nerve (RLN) injury was noticed, while one chylothorax was managed conservatively.

The mean LOS was 18.5 ± 11.7 (range: 8-56) days, and no significant differences among the groups were observed (Table 3). The hybrid approach did not affect the LOS as expected in a positive way, despite the earlier mobilization and the less postoperative pain which were obvious in this group. This observation may be attributed to the prolonged need for total parenteral nutrition, the gradual escalation of the feeding through the jejunostomy, and the progressive initiation of oral nutrition after the seventh postoperative day when a leak test is performed. So, even when no postoperative complications exist, the adjustment of the patients to their new nutritional status and finding the balance between oral feeding and supplementary feeding through the jejunostomy so that adequate calorie intake is provided and no gastroin-

testinal disorders are caused requires time and hospitalization, regardless of the surgical approach used.

The transhiatal approach was preferred in cases with significant comorbidities, especially cardiopulmonary disease such as coronary artery and chronic obstructive pulmonary disease, and as a result, higher ASA scores in order to reduce the mean operative time and the complication rates (Pearson chi-square =9.864, df=2, p=0.007). In contrast, age alone was not a significant factor for the choice of the operation (t-test, p=0.687). Indeed, the severe postoperative complications were significantly fewer in the transhiatal group (Pearson chi-square =4.241, df =1, p =0.039), suggesting that the transhiatal approach is a safe alternative for patients with severe comorbidities.

The possibility of severe postoperative complications was not significantly associated with age (p =0.326), sex (p =0.704), NAC (p =0.062), preoperative radiotherapy (p =1), T stage (p =0.299), and N stage (p =0.577). However, there is a statistically significant association between the location of the tumors and the major postoperative complications (p =0.037), with tumors located in the middle esophagus presenting higher severe postoperative complications rates (80 %), followed by tumors located in the GEJ (52.17 %), in contrast with tumors located in the lower esophagus (18.2 %).

Regarding the oncological outcome, all resection

Table 4: Overall number of complications based on Clavien-Dindo Classification for the 75 patients who underwent esophagectomy due to esophageal cancer divided according to the surgical approach (open, hybrid, transhiatal).

	Total cohort (n =75)	Open (n =30)	Hybrid (n =28)	Transhiatal (n =17)	p	Open vs Hybrid
I	12 (16)	5 (6.7)	5 (6.7)	2 (2.6)	0.856	0.904
II	39 (52)	11 (14.7)	18 (24)	10 (13.3)	0.089	0.035
IIIa	7 (9.4)	4 (5.3)	2 (2.6)	1 (1.3)	0.639	0.439
IIIb	8 (10.6)	4 (5.3)	2 (2.6)	2 (2.6)	0.737	0.439
Iva	3 (4)	2 (2.6)	0	1 (1.3)		
IVb	0 (0)	0	0	0		
V	6 (8)	4 (5.3)	1 (1.3)	1 (1.3)	0.366	0.185
Major (\geq IIIb)	17 (22.7)	10 (13.3)	3 (4)	4 (5.3)	0.100	0.039

Values are given as number and percentage in brackets. n =number.

Table 5: Specific complications occurring in the 75 patients who underwent esophagectomy due to esophageal cancer divided according to the surgical approach (open, hybrid, transhiatal).

	Total cohort (n =75)	Open (n =30)	Hybrid (n =28)	Transhiatal (n =17)	p	Open vs Hybrid
Anastomotic leak	8 (10.6)	5	3	0		0.511
Necrosis of the conduit	3 (4)	2	1	0		0.594
Anastomotic stenosis	1 (1.3)	0	1	0		
Injury to major airways	2 (2.6)	1	1	0		0.960
Pleural effusion requiring drainage	2 (2.6)	2	0	0		
Pneumonia	7 (9.3)	6	1	0		0.054
Tracheostoma	4 (5.3)	2	1	1	0.865	0.594
Respiratory failure requiring intubation	7 (9.3)	5	1	1	0.197	0.101
Chylothorax	1 (1.3)	1	0	0		

Values are given as number and percentage in brackets. n =number.

margins were negative in all groups. The mean total number of lymph nodes was 26.3 for the open group and 33.8 for the hybrid group, without statistically significant difference (independent samples t-test, $p=0.169$) (Table 3). Likewise, there was no statistically significant difference concerning the positive lymph nodes (Mann-Whitney test, $p=0.934$). Based on these results, it is a fact that the oncologic efficiency of the thoracoscopic approach is equivalent to the conventional open, regarding short-term outcomes.

Further subgroup analysis was performed to investigate possible differences between each type of esophagectomy and the surgical approach. Regarding Ivor Lewis esophagectomy, no statistically significant difference was found in terms of major postoperative complications ($p=1$), mortality ($p=0.333$), LOS ($p=0.138$), and total number of lymph nodes dissected (t-test, $p=0.966$), between the open and the hybrid group. Regarding McKeown esophagectomy, there were statistically significant less severe postoperative complications ($p=0.026$), but no significant difference in terms of mortality ($p=0.231$), LOS ($p=0.623$), and the total number of lymph nodes resected (t-test, $p=0.125$). These findings suggest that the hybrid thoracoscopic approach is not only as safe and adequate in terms of lymphadenectomy as the open one, but it is also associated with significantly less severe postoperative complications, especially for McKeown esophagectomy.

Regarding long-term results, Kaplan Meier survival analysis with log-rank test indicated no statistically significant difference in terms of OS and DFS among the three groups ($p=0.582$ and $p=0.172$, respectively), as demonstrated in Figure 1 and Figure 2, as well as specifically between the conventional open group and the hybrid group ($p=0.631$ and $p=0.125$, respectively). One-year OS was 76.6 % (23/30) for the open group, 85.7 % (24/28) for the hybrid group, and 52.9 % (9/17) for the transhiatal group. One-year DFS was 63.3 % (19/30), 85.7 % (24/28), and 47 % (8/17), respectively. Three-year and 5-year survival cannot be estimated yet, which discloses one of the limitations of this study.

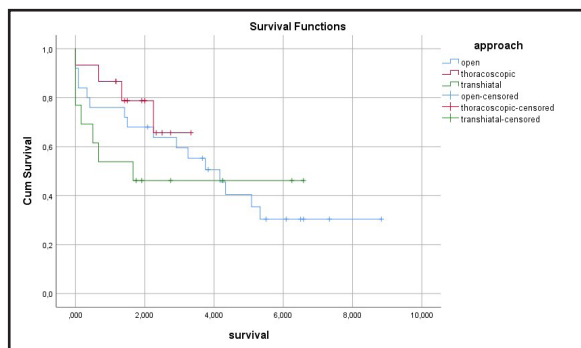


Figure 1: Kaplan Meier survival analysis curve demonstrating the overall survival of the patients' groups according to the surgical approach (open, hybrid, transhiatal).

Discussion

Esophagectomy is one of the most complex and demanding procedures in general surgery, as it requires two- or three-field operation and a thorough lymphadenectomy and has a significant impact on patients' quality of life. The mortality rates vary from 0.6 %⁴ in experienced centers to almost 23 % in centers with low volumes of patients⁵.

It is frequently associated with a variety of respiratory complications (RC), such as consolidations, pleural effusions, lower respiratory tract infections, acute respiratory failure, and, therefore, adult respiratory distress syndrome (ARDS), which may require mechanical ventilation, and represents the leading cause of mortality and in-hospital morbidity⁶. Open esophagectomy causes significant injury to the chest wall muscles and postoperative pain, which restricts coughing and expectoration⁷. Smoking, increased ASA score, cardiovascular comorbidities, and long hospital stay are negative prognostic factors^{6,8}. RC might affect not only the short-term survival but also the relapse-free survival and the overall survival, suggesting an independent prognostic factor⁸. Minimal invasive esophagectomy (MIE) may reduce the incidence of RC without negatively affecting the mortality and the oncological outcomes⁹. In a recent meta-analysis by Murakami et al¹⁰, which involved 21,057 patients, the superiority of thoracoscopy in terms of RC and particularly pneumonia was observed in randomized control trials and retrospective cohort studies from high-volume institutions. In our cohort, hybrid thoracoscopic esophagectomy was related to a significantly lower incidence of respiratory failure requiring intubation compared to the open approach (Table 5).

However, the complete elimination of RC after esophagectomy is impossible, especially in comorbid patients or patients who have developed severe postoperative complications. Careful preoperative recognition and management of respiratory infections, with sputum microbiology, targeted antibiotic prophylaxis, and treatment of clinically silent infections, has been proposed to reduce mortality caused by RC⁶. The preoperative improvement of lung function as well as the early extubation with

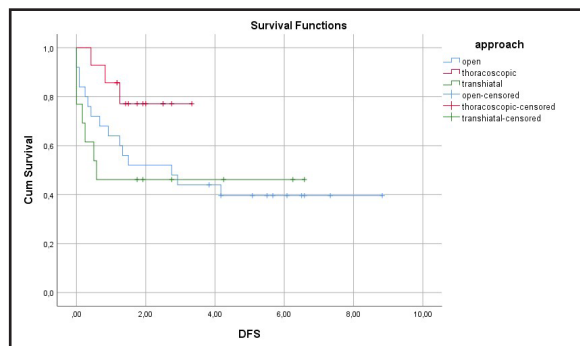


Figure 2: Kaplan Meier survival analysis curve demonstrating the disease free survival of the patients' groups according to the surgical approach (open, hybrid, transhiatal).

weaning within 24 hours after surgery are helpful preventing RC⁶. Epidural analgesia is another valuable tool for the prevention of postoperative RC¹¹.

Except for the RC, other benefits of the thoracoscopic approach, in comparison with the standard open, include better exposure and visualization of the thoracic duct, fewer wound infections, fewer lung injuries and cardiac arrhythmias such as atrial fibrillation, a significant reduction in incisional pain as rib spread is avoided^{5,12}, and easier access to the superior mediastinum for the completion of the lymphadenectomy. Specifically, the thoracoscopic approach enables a more radical and meticulous Japanese style three-field lymphadenectomy, achieving higher numbers of resected lymph nodes from the high mediastinal paratracheal station and the recurrent laryngeal nerve station¹³. No chylothorax occurred in the hybrid group in this cohort. Although the mean number of total lymph nodes extracted was higher in the thoracoscopic compared to the open group, 33.8 and 26.3, respectively, no statistically significant difference was proven.

Whether the thoracoscopic resection should be preferably performed in the prone or left lateral position is still an unresolved issue. On the one hand, the prone approach offers better oxygenation and ergonomics by removing the blood from the operative field and eliminating the need for lung retraction¹⁴. So far, the studies have shown no significant difference, but their small samples do not allow us to reach safe conclusions. Thoracoscopic esophagectomy in the prone position resulted in significantly fewer postoperative respiratory complications when it was combined with hand-assisted laparoscopy rather than traditional laparotomy, indicating the role of abdominal trauma in pulmonary function during the early postoperative period¹⁵. In our study, we performed all the thoracoscopic procedures in the left lateral position.

For high-risk patients with severe comorbidities but operable disease, the dilemma between transhiatal and hybrid thoracoscopic procedures has become apparent. A single-center retrospective study by Jinek et al¹⁶, reported a significantly lower overall complication rate for the hybrid group but no statistically significant difference regarding mortality, pulmonary complications, and number of resected lymph nodes.

Another topic of interest is the superiority of thoraco-laparoscopic esophagectomy. Total minimally invasive surgery (MIS) is accompanied by less postoperative pain, but it requires a longer operative time than hybrid¹⁷. According to a recent network meta-analysis of only randomized control trials by Szako et al¹⁸ comparing all types of esophagectomy, the complete thoraco-laparoscopic approach was related to fewer RC (relative risk =0.49, 95 % CI: 0.23-0.99). In contrast, the transhiatal approach had significantly shorter operative times. Regarding postoperative morbidity and LOS no significant differences were recorded. Another meta-analysis by Su et al⁷ indicated significantly better pulmonary function one month after surgery for the patients who underwent total MIS. A distinct type of hybrid esophagectomy which combines

laparoscopy and right lateral thoracotomy has been adopted by some centers instead of total MIS. The advantages of this approach include less abdominal trauma and easier access to the thoracic cavity for the construction of the intrathoracic anastomosis, in the case of Ivor Lewis esophagectomy¹¹.

Robotic esophagectomy (RE) is becoming increasingly popular in developed countries, thanks to its three-dimensional view and better ergonomics, with encouraging results being published and similar outcomes regarding survival¹⁹. A specific advantage of RE is the more straightforward and more thorough dissection of lymph nodes along both RLNs²⁰, resulting in significantly fewer vocal cord paralysis¹⁹. In addition, the incidence of postoperative pneumonia appears to be significantly lower in the total RE group¹⁹. Hybrid procedures, using the robotic approach for the thoracic phase, combined with laparotomy or laparoscopy, were initially performed in many centers before proceeding to total RE²⁰. Most of the literature consists of single-center studies applying a variety of hybrid procedures since complete RE requires specific training and significantly longer operative time¹⁹, while most of the surgeons are familiar with laparoscopy²⁰. Regarding Ivor Lewis esophagectomy, a combination of robotic-assisted thoracoscopic approach with laparotomy showed similar outcomes compared to the completely open approach, even for LOS and postoperative pneumonia treated with antibiotics, according to a case-matched analysis from a single center²¹. The same authors noticed that a higher proportion of ASA grade III patients were included in the robotic-assisted group, pointing out that surgeons felt more confident providing MIS to these patients, without increasing morbidity and mortality²¹. A meta-analysis comparing robotic and thoracoscopic approaches for the McKeown procedure showed similar results between the two methods in terms of resection margins, extent of lymphadenectomy, total complications, and mortality, while significantly higher rates of postoperative pneumonia were noticed in the thoracoscopic group²². Our hospital does not yet provide access to robotic surgery; however, laparoscopic procedures are widely performed in our department.

Anastomotic leak and conduit necrosis constitute two of the most dreadful complications of esophageal surgery, accompanied by increased morbidity and mortality. Endoscopic procedures application, such as self-expandable stents and endoluminal vacuum-assisted therapy, may reduce the necessity of reoperation, offering valuable tools, especially in the era of MIS surgery^{21,23}. In addition, the intraoperative use of fluorescence with indocyanine green (ICG) to assess the perfusion of the conduit contributes to the prevention of the anastomotic leak, especially in cervical anastomosis, which is more prone to leakage²⁴. No difference was proven in regards to ICG administration and intrathoracic anastomosis^{24,25}. The involvement of biomedical engineering has provided essential methods not only for the management, but also for prevention of these severe complications.

The financial aspect of MIE is another topic of interest. The total cost comprises the intraoperative cost, including anesthesia and equipment, and the hospitalization cost, which involves ICU stay, pharmaceutical, imaging, and physical therapy costs²⁶. Intraoperative cost, which represents almost one-third of the total hospital cost, is higher for the total MIS group, as a result of the increased intraoperative time, followed by the hybrid group, while the transhiatal approach appears to be the least expensive one, followed by the open approach²⁶. However, MIS is associated with shorter LOS in the ICU^{26,27}, and ultimately, no significant difference concerning the total hospital cost is estimated among the groups²⁶. Severe postoperative complications, such as pneumonia, reintubation, anastomotic leak²⁶, renal failure, and reoperation²⁸, increase the hospitalization cost. High-volume centers show a tendency to minimize the cost as the proportion of postoperative complications is significantly lower²⁹. Patient-related preoperative factors, such as increased age, coronary disease, hypertension²⁶, and body mass index above 30²⁸, were also associated with increased cost. The cost-effectiveness of MIE is supported by other authors as well³⁰, who even report less hospital cost and better quality of life in comparison to the open approach²⁷. The results of the ROBOT trial, a randomized clinical trial, are also interesting, as they demonstrate similar costs between robotic and open esophagectomy, with the robotic group developing fewer postoperative complications³¹.

Last but not least, total MIE requires an extended learning curve to avoid complications such as anastomotic leak and recurrent laryngeal nerve injury, and it is associated with longer intraoperative time and higher cost compared to both hybrid and open approach¹⁷. The learning curve for thoracoscopic esophagectomy is shorter in comparison to the RE³². In other words, the hybrid thoracoscopic approach may represent the golden ratio, as it combines shorter learning curve, less operative time and therefore surgical equipment cost than the total MIS, and less operative pain than the conventional open approach¹⁷.

There may be limitations in the current study, including the relatively small sample size and the short follow-up period, especially for the thoracoscopic group. In addition, it is a retrospective study and randomization was not performed. The different types of esophageal resection, McKeown and Ivor Lewis, add heterogeneity within the groups. The possibility of selection bias concerning the classification of the patients to each surgical approach group, conventional, hybrid and transhiatal, cannot be excluded. Future research from our institution aims to increase the number of patients undergoing thoracoscopic esophagectomy and their follow-up period to acquire more long-term results. We would also like to investigate the potential superiority of the thoracoscopic approach in the prone position in comparison to the lateral one in terms of intraoperative time, blood loss, postoperative complications, lymph node resection, and survival.

To sum up, the hybrid thoracoscopic esophagectomy

offers the advantages of minimally invasive surgery, such as less postoperative pain, earlier mobilization, and lower RC rates. Meanwhile, it requires less operative time and a shorter learning curve than total minimal invasive, suggesting the best alternative regarding cost-effectiveness, especially in low-volume centers. For these reasons, it is the procedure of choice in our department. The first results from our experience are promising and satisfactory, as the hybrid procedures are safe and oncologically efficient. In the short-term future, the advantages of the hybrid approach will be more obvious.

In conclusion, the hybrid thoracoscopic esophagectomy is proven to be a safe and feasible procedure, with equivalent oncologic outcomes to the conventional open approach and significant advantages concerning postoperative pain and morbidity, even in mid-volume centers. However, the transhiatal approach is still an alternative for patients with severe cardiopulmonary comorbidities.

Conflict of interest

Authors declare no conflicts of interest.

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