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Clinical implementation of minimally invasive esophagectomy

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Summary

Background Minimally invasive surgery is becoming the method of choice for the resection of esophageal cancer worldwide. Methods: Retrospective analysis of prospectively collected clinical data in a tertiary care center with a detailed description of the course of the program.

Results A total of 136 transthoracic esophageal resections were performed between 2010 and 2023. The study group included 116 operations, 69 of which were fully minimally invasive and 47 hybrid. 80.0% of the study group underwent surgery using a multimodality approach. The median operation time was 431 min (± 103). The R0 resection rate was 100%. Forty-two patients (36.2%) had no postoperative complications. The postoperative Clavien-Dindo > IIIb morbidity was 27%. The postoperative 90-d mortality rate was 1.7%. The average number of lymph nodes removed in the last quarter of cancer patients was 31. The anastomotic insufficiency rate for reoperation was 4% (Ivor-Lewis 4.2%, McKeown 5%).

Conclusions With extensive expertise in high-end minimally invasive abdominal and thoracic surgery, implementation of a minimally invasive esophageal resection program with a clinical and oncologic outcome within generally accepted limits is feasible.

Keywords Esophagus, Esophageal tumor, Esophagectomy, Surgical oncology, Perioperative medicine, Pathology, surgical

Introduction

Surgical resection is the mainstay of treatment for esophageal cancer. In locally advanced stages without distant metastases, the curative approach significantly improves survival if multimodal treatment, including perioperative chemotherapy (e.g., FLOT) or neoadjuvant radiochemotherapy (e.g., CROSS) is performed [1–7].

Nevertheless, the operation is demanding and often involves an abdominal and thoracic approach with single-lung ventilation. In the past, postoperative morbidity and mortality have been high, which is why various attempts have been made to reduce the burden of esophageal resection [4]. In addition to early enteral nutrition, epidural anesthesia, early mobilization, etc., hybrid or fully minimally invasive techniques aim to reduce postoperative pain, improve early postoperative mobilization, and provide more efficient respiratory therapy [8–15].

However, the oncological completeness of the resection, including a sufficient R0 rate and adequate lymph node removal, is a prerequisite [16].

By and large, esophageal resections were introduced relatively late in the introduction of minimally invasive procedures in abdominal and thoracic surgery [17]. On the one hand, the operation itself is a challenge, and on the other hand, video-assisted thoracic surgery (VATS) was developed later than laparoscopic surgery. Both

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parts, abdominal and thoracic surgery, required a high level of expertise to achieve a low complication rate and a satisfactory oncological outcome. Only then does minimally invasive surgery make sense and is justifiable for the patient. One consequence of all this is that entirely minimally invasive oesophageal resections only became standard practice later and almost exclusively in specialized centers with a high level of expertise in thoracic and abdominal minimally invasive surgery.

For a long time, it needed to be clarified whether it was worth the effort. Recently, several publications have demonstrated a clear advantage for the patient regarding early mobilization, reduction of postoperative pain, pneumonia rate, lymph node removal, blood transfusions, and achievement of postoperative chemotherapy [18–22]. By 2017 at the latest, however, the TIME trial showed that minimally invasive esophageal resection is on par with open resection in terms of oncology and is superior in the peri- and postoperative course [23].

Ten years ago, our department formed a specialized team to gradually introduce the minimally invasive approach to esophageal resections. This team consisted of two abdominothoracic surgeons, one with more experience in VATS and the other with more experience in upper gastrointestinal surgery, including bariatric surgery.

After more than 100 procedures, it is time to review the implementation process, the development of our technology, and the perioperative and oncological results.

Objectives

In this document, we present our center's experience in an area with a low incidence and a relatively small number of cases regarding the implementation and consolidation of minimally invasive esophagectomy within our department. The emphasis lies in delineating the learning curve, the progression of our surgical technique, and the juxtaposition with other facilities.

Patients and methods

The study group consists of all patients who underwent fully minimally invasive surgery or a hybrid approach. In other words, only minimally invasive Ivor-Lewis (intrathoracic anastomosis) and McKeown (cervical anastomosis) procedures were included. Twenty open esophagectomies, open transhiatal abdominal procedures and cervical jejunal interpositions were excluded. Patients with esophageal neoplasia underwent detailed preoperative evaluation, including gastroscopy with biopsies, colonoscopy, endoscopic ultrasound, PET-CT scan of the neck and trunk, and spiroergometry. Bronchoscopy and ENT endoscopy were performed for squamous cell carcinoma. For locally advanced esophageal cancer patients, our multidisciplinary gastrointestinal tumor board utilized a guideline-based, personalized multimodal approach.

Four to eight weeks after neoadjuvant treatment, patients underwent a PET-CT scan to exclude those with newly developed distant metastases from surgery. In addition, a preoperative gastroscopy with biopsies was performed to determine the endoscopic degree of tumor regression.

Mucolytic (N-acetylcysteine) and broncholytic agents (fenoterol and ipratropium inhalations) as well as respiratory therapy were started at least one day before the operation. Whenever possible, a peridural analgesia catheter (PDA) was placed. All patients received perioperative antibiotics and intravenous corticosteroids (100 mg Urbason®) prior to surgery. In the first 36 patients, the abdominal part of the operation was conventionally performed through an upper midline incision in the supine position, while the thoracic part was already performed with VATS. A laparoscopic approach was then performed in the French position with a bean bag on the patient's back. Five trocars were placed in a U-shaped arrangement, supplemented by a Nathanson retractor subxyphoidally for the left liver (Fig. 1). During the abdominal portion, the transition zone at the greater curvature between the right and left gastroepiploic

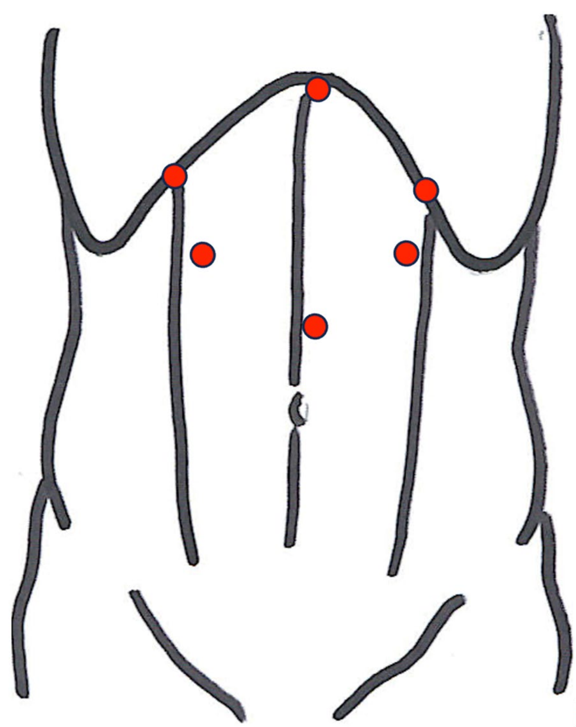

Fig. 1 Trocar position for the abdominal part of the minimally invasive esophageal resection

arteries was marked with a single suture to identify the ideal site for subsequent placement of the circular stapler. Before placing the first linear staplers for placement of the gastric tube, 20 mg Buscopan ® (butylscopolaminium bromide, Sanofi-Aventis Deutschland GmbH) was administered i.v. to relax the gastric muscles and thus obtain a longer conduit by stretching before closing the staple lines.

In the first third of the patients, a left-sided decubitus positioning with a curved table for a dorsal approach with five trocars according to the Pittsburgh/Luketich technique [24–26] was chosen for the thoracic part. In retrospect, the ventral approach with three incisions, protected by an Alexis retractor (Bard Inc., Intl.), seemed more practical. The placement of three small thoracocentesis thus corresponds to our standard approach for VATS lobectomies, but more dorsally [27].

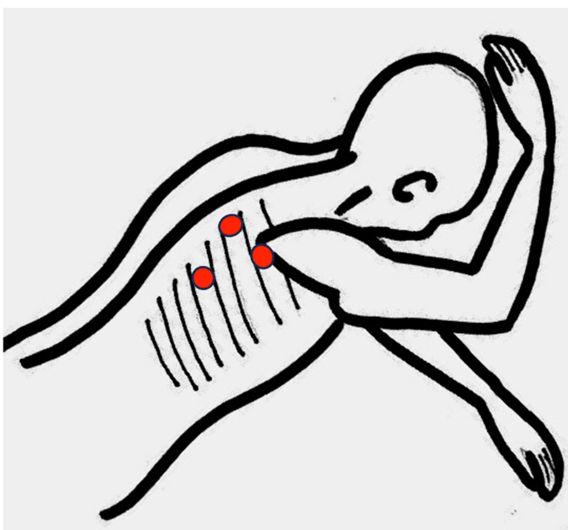

Fig. 2 45° semi-recumbent position for the thoracic part of the minimally invasive esophageal resection. The red dots symbolize the position of the mini-thoracocentesis

The patient's positioning was then changed to a left-sided position with a 45-degree forward tilt (semi-prone position, Fig. 2), which allows gravity to be used to keep the lung out of the surgical field and avoid its trauma [28]. In an emergency, the table would need to be tilted backwards for conversion to an open thoracotomy to allow an open dorsolateral approach through the fifth intercostal space.

The objective was to completely remove the esophagus and its surrounding lymph nodes (ATS 7, 8, 4L, 4R) in a single piece, including the entire thoracic duct, and to extract any potentially problematic lymph nodes identified through imaging.

A 25-mm circular anastomosis with double-row 4.8-mm staples (EEA XL, Medtronic Inc., Intl.) was used together with an orally inserted anvil (DST Series® CEEA® OrVil®, Medtronic Inc., Intl.). After stapling, a gastroscopic underwater leak test was performed. Starting in 2017, we routinely wrapped a pedicled omental fat flap around the anastomosis. Later, we used ICG staining (Pinpoint®, Stryker Inc., Intl.) to check perfusion in some patients (Fig. 3). In most cervical anastomoses, a neurstimulator (Neurosign®, Technomed Inc., Intl.) was used to anatomically identify the recurrent laryngeal nerve and to finally check its function before closing the neck wound.

At the beginning, we routinely performed a pyloroplasty. After 30 cases, we abandoned this step in order to reduce the operating time and potential complications. Whenever clinically necessary, we performed postoperative pyloric balloon dilatation (3 cm, Rigiflex®II, Boston Scientific, Intl.) under conscious

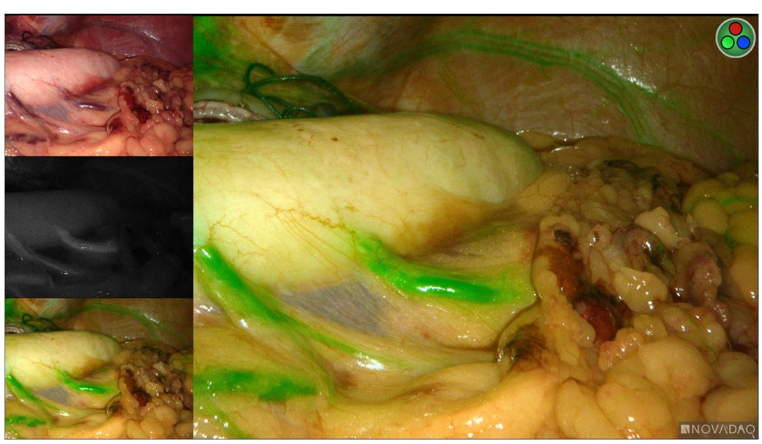

Fig. 3 Induced fluorescence of indocyanine green—tissue angiography of a gastric canal

sedation [29, 30]. This was considered part of the treatment and not a complication.

As of 2019, two thoracic 28F drains with underwater seals were routinely placed together with a Jackson-Pratt drain [31] (Jackson-Pratt® flat drain with bulb, Cardinal Health Intl.) with gentle suction behind the gastric pull-up to drain the anastomotic area. For cervical anastomoses, an easy-flow drain was left in place until the tenth postoperative day, running directly along the wound to the skin surface. Intraoperatively, a nasogastric tube was inserted for decompression while CPAP (continuous positive airway pressure) ventilation therapy was administered.

Postoperatively, the PDA catheter remained in place with the urinary catheter for three days. Patients were always upright at 20–30° to avoid reflux and aspiration. Enteral nutrition was started on the first day with 20 ml/h of Intestamin® (Fresenius Kabi Austria GmbH). Immediately after surgery, oral intake of small amounts of water was allowed. On the third day, soft food was started if the clinical situation allowed it. Postoperative respiratory therapy and early mobilization were supported by physiotherapists. The chest drains were removed when there was no more blood, air, or chylous discharge and the total volume was less than 200 ml. In addition to generous analgesic therapy, enemas, and lactulose p.o. were routinely administered.

Lifelong therapy with a proton pump inhibitor (PPI) of 40 mg bid was started. The jejunum catheter was left in place until two weeks after discharge to compensate for possible malnutrition. At this last surgical visit, the further course of treatment, as suggested by the tumor board based on the final histology, was discussed with the patient. All patients were treated according to a generally recognized oncological regimen.

As the patient population is heterogeneous and limited in number, only descriptive statistics were chosen. The data are presented as mean or median (med), minimum (min), maximum (max) and interquartile range (IQR). Where appropriate, the standard deviation (SD) was calculated. Survival was calculated according to Kaplan-Maier. Postoperative complications were classified according to Clavien-Dindo [32].

Results

Operations

The program began in February 2010, and since then, one hundred and thirty-six transthoracic esophagectomies have been performed. Initially, three open esophagectomies were performed to train the team and discuss the key steps. Subsequently, 26 patients underwent a hybrid Ivor-Lewis esophagectomy combining a median laparotomy with a right-sided thoracoscopy. Subsequently, 69 fully minimally invasive Ivor-Lewis esophagectomies were routinely performed. The twenty McKeown esophagectomies were always performed as hybrid operations, i.e., thoracoscopy combined with laparotomy.

Patients

The age of the patients at the time of surgery was between 9 and 79 years (Med 63, IQR 56–68.2). The mean BMI was 25 kg/m2 (IQR 23-28 kg/m2). One hundred and twelve (96.6%) patients underwent resection for malignant disease, and four (3.4%) had benign disease requiring urgent esophageal resection (two end-stage achalasia, one leiomyoma, one caustic stenosis). Of the 112 patients with esophageal cancer, 95 underwent preoperative therapy: 48 (50.5%) had received neoadjuvant radiochemotherapy, 46 (48.4%) had received chemotherapy, and one patient (1.1%) had received both. After neoadjuvant therapy, 7% of patients had to be excluded from surgery due to progressive disease with distant metastases.

Pathology

The R0 resection rate was 100%. The pathology was adenocarcinoma in 30.2%, squamous cell carcinoma in 65.5% (including verrucous carcinoma), and adenosquamous carcinoma in one case (0.9%). The remaining 3.4% of pathologies were benign.

The average number of lymph nodes removed from cancer patients was 28 (IQR 20–38.5).

The survival curves (Kaplan-Maier curve) are shown in Fig. 4.

Clinical results

The median operation time was 431 min (± 103). The median number of packed red blood cells administered intraoperatively was zero.

There were two conversions (0.9%) from minimally invasive to open, one for suturing a bronchial laceration and the other for total gastrectomy in a patient with a residual tumor in the frozen section at the gastric resection margin.

Three minimally invasive esophageal resections were redos after laparoscopic fundoplication.

The median hospital stay was 20 days (IQR 15–29 days).

Forty-two patients (36.2%) had no postoperative complications.

Minor postoperative complications (Clavien-Dindo I-IIIa) occurred in 35%. Postoperative severe morbidity (Clavien-Dindo IIIb) amounted to 27%.

The postoperative mortality rate over 90 days was 1.7% ($n=2$). One patient died from a bronchial lesion caused by the overtube for endoscopic vacuum therapy of a small anastomotic leak. One patient died immediately from myocardial infarction on postoperative day 24 [33].

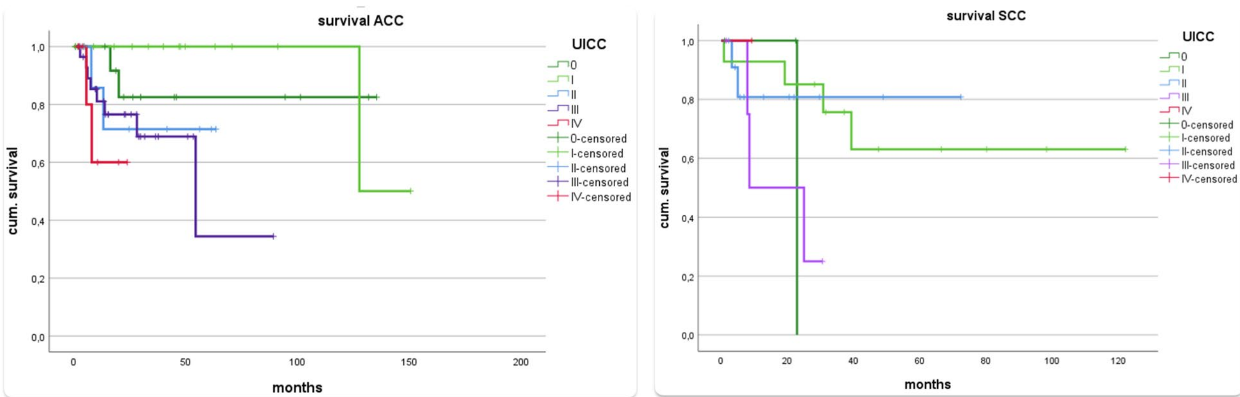

Fig. 4 Cumulative survival rate of patients with esophageal malignancies according to their UICC stage: (**a**) patients with adenocarcinoma (**b**) patients with squamous cell carcinoma

Of all 116 patients, 24 developed anastomotic insufficiency (20.7%), two (1.7%) had rebleeding (= two reoperations), 13 (11.2%) had a chylous leak (= four reoperations), one (0.9%) had a recurrent nerve palsy, six (5.2%) had a wound infection (three SSI I, three SSI III), one (0.9%) developed a herniation of the small intestine into the chest (lap. reoperation).

The complications in all patients are shown in Table 1.

Anastomotic leaks occurred in 21 of our 96 Ivor-Lewis patients (21.8%) and three of the 20 McKeown operations (15%). The rate of anastomotic leakage requiring reoperation was 4% (four Ivor Lewis patients, 4.2%, and one McKeown patient, 5%).

17 (17.7% of 96) Ivor-Lewis patients could be cured non-surgically, and four (4.2% of 96 Ivor-Lewis patients) required one or more operations.

Of the 20 hybrid McKeown esophageal resections, one anastomotic insufficiency (5%) was re-operated (insertion of a T-tube), and one (5%) was treated endoscopically.

Endoscopic re-interventions were performed in 19 patients (16.4%): Ten patients received an esophageal stent (Niti-S®, Taewoong Medical, Intl.), six were treated with endoscopic vacuum therapy (EsoSponge®, B. Braun SE, Melsungen, Germany), which was then changed every three to five days until granulating tissue was seen at the base of the insufficiency. The decision for one or the other procedure was at the discretion of the treating surgeon. During the study, there was a shift from stenting to endoscopic vacuum therapy [34]. Three more minor leaks were treated with endoscopic clips and/or fibrin glue.

The reoperation rate for all causes was 18% (21 of 116): Seven anastomotic insufficiencies (6%, including two with esophagotracheal fistula), four empyema (3.4%), four chylous fistulas (3.4%), three SSI I-III (2.6%), two re-bleeds (1.7%), one hiatal hernia (1.7%).

41.4% of patients had one or more medical complications: Thirty-nine respiratory complications (14 pleural effusions, eleven pneumonias, six empyema, six respiratory insufficiencies, one pneumothorax, one pulmonary embolism), twelve cardiac complications (ten atrial fibrillation, two cardiac insufficiencies with ECMO, one myocardial infarction), eight neurological complications (delirium, cerebral seizure), five urinary tract infections, three septic infections of the central venous catheter, one thrombophlebitis.

To illustrate our learning curve, we compared the first quarter of our patients with the last quarter. The rate of anastomotic insufficiency and reoperation did not change significantly, but the surgical radicality of the esophagectomy did. In the first quarter of patients, a median of 25 lymph nodes were removed. In the last quarter, the median number of lymph nodes was 31. Remarkably, the operation time increased from a median of 412 min (IQR) to a median of 432 min, mainly due to the refinement of our technique described above. Hospital stay was reduced from a median of 24 days (IQR 14.3–33.0) at baseline to a median of 14 days (IQR 11–19.8) in the last quarter of patients. The number of minimally invasive and hybrid esophageal resections per year was significantly increased from 7.3 in the first three years to 17.3 per year on average from 2017 to 2020.

In the 69 fully minimally invasive Ivor-Lewis procedures, a decrease in anastomotic insufficiencies from four to two was observed, along with a reduction in the median hospital stay from 19 to 16 days when comparing the first quarter ($n = 17$) to the last quarter ($n = 17$). However, there were no significant changes in mortality, morbidity, and reoperation rates.

Discussion

What we have found

Ten years ago, we introduced a minimally invasive program for transthoracic esophageal resection in a tertiary care center (University Hospital) by copying all the steps of Luketich's experience at UMPC (Pittsburgh) [24]. With increasing experience, we modified the thoracic part of the surgical technique from a posterior five-trocar technique to an anterior three-trocar approach in a semi-recumbent position. We retrospectively analyzed 116 minimally invasive esophageal resections in 112 patients with esophageal cancer and four patients with benign disease leading to esophageal resection.

We found that we were able to achieve a generally accepted perioperative morbidity with a reoperation rate of 4% due to anastomotic insufficiency and a 90-day mortality of 1.7% [35, 36]. Furthermore, with an R0 rate of 100% and a mean lymph node count of 31 in oncological cases, at least the current oncological standards were achieved. It remains to be seen whether this will translate into a long-term survival benefit.

We were able to establish a clear learning curve in terms of the number of lymph nodes removed per case. In addition, the reoperation rate and the anastomotic insufficiency rate decreased. However, direct comparability is not possible due to the number of cases and heterogeneity of the constantly evolving method. This also applies to the length of hospital stay, which was reduced from a median of 24 days to 14 days. However, despite increasing technical experience, the operation time increased, which is presumably due to the technical changes mentioned above.

The learning curve was not only reflected in a reduction of complications and hospitalization time, but also in the modification of the approaches with successive reduction of thoracocenteses and standardization of the abdominal trocar position.

Table 1 Postoperative complications after Clavien-Dindo

	n	%	
Total	116	100	
0	42	36,2	**36% No**
I	7	6,0	**35% Minor**
II	21	18,1	
IIIA	13	11,2	
IIIB	22	19	**27% Major**
IVA	7	6	
IVB	2	1,7	
V	2	1,7	**1.7% Mortality**

A retrospective multinational cohort study published in 2022 confirmed that a significant learning curve with learning-related morbidity is associated with the clinical implementation of minimally invasive esophageal resection according to Ivor Lewis. Centers with high case numbers (> 30 cases per year) appear to be able to achieve an acceptable level of safety more quickly [37]. In contrast to the Swedish experience [38], in this study, fellowships, long-term residencies and supervision by a proctor do not appear to guarantee successful implementation of a minimally invasive esophageal resection program. Our center won't reach the recommended 30 esophageal resections per year in the near future. Currently, we have two surgeons who can independently perform the operation, but we lack the resources for longer study stays in large high-volume centers. Based on our experience, it's important to stay in touch with experienced colleagues and large centers to discuss difficult situations and seek help when needed.

Due to the specialization and the generally accepted results, we were able to significantly increase the number of cases per year. With more than 20 minimally invasive esophageal resections per year (together with our minimally invasive proximal gastric resections with double tract reconstruction), we can finally be described as a "high volume center" [39].

Strengths and weaknesses of the study

Since we started our minimally invasive esophageal program as a low volume esophageal resection center, higher morbidity would have been considered normal initially. With an initial five to eight esophageal resections per year, the learning curve was flat. For low-volume centers, a mortality rate of up to 12% and a median length of stay of 30 days was recently published in Germany [39]. However, with two experienced surgeons for minimally invasive surgery (see "Patients and methods"), we were able to achieve a reoperation rate of 4% due to anastomotic insufficiency, a mortality rate of 0% and a median length of stay of 24 days in the first quarter of our program.

Due to the evolutionary strategy and the relatively small number of cases, comparing an early cohort with a later cohort in which the positioning, access, and surgical technique are exactly the same cannot be carried out. With the current planned implementation of robot-assisted esophagectomy at our center, the approach and surgical strategy will change. Due to the evolutionary nature of the program, deeper insights from the learning curve cannot be significantly derived.

Without doubt, a randomized controlled prospective design of this study would be better suited to compare MIE with open surgery. Clearly standardized criteria for patient selection and a clear differentiation of the few benign entities would reduce the selection bias. Unfortunately, due to the low incidence and the principal assignment to MIE, only retrospective follow-up is methodically feasible from the available data.

Relevance for the current literature

Given the current literature, a surgically relevant anastomotic leakage rate of 4% is well within the normal range even when compared to high-volume centers [21, 35, 36, 40–45]. Modification of our technique over time could reduce endoscopically treated minor leaks. Initially, we started to over-sew the double-row circular esophagojejunostomy staple suture with manual sutures, first with eight interrupted 4–0 Vicryl® sutures (Ethicon®, Intl.), and later with a running absorbable 3–0 barbed suture (3–0 V-lock®, Medtronic Inc., Intl.). Then we started to invert the linear staple suture at the esophageal end with one or two purse-string sutures (2–0 Ethibond®, Ethicon®, Intl.) in the middle to the circular staple suture to avoid cross-stapling. The next improvement step was the use of an omental fat pad derived from the greater curvature. It was placed dorsally on the left side and then wrapped ventrally around the anastomosis to cover the entire circular suture line and, if large enough, the entire candy cane. In addition, the diameter of the gastric tube was increased from the original 3–4 cm to 4–5 cm. This should allow the oblique intramural gastric vessels to improve blood supply of the anastomotic region [46, 47]. The diameter of the gastric conduit has often been debated. If it is smaller, peristaltic bolus clearance might be better. Consequently, GERD may be reduced. Therefore, our open cases started with a 3 cm narrow tube. Switching to a 4–5 cm diameter tube facilitated insertion of the circular 25 mm wide stapler and avoided distension trauma. In addition, the oblique intramural gastric vessels could improve blood supply, as described above [46].

However, the reoperation rate due to various diseases was high (19%). However, the significance of a complication is not solely determined by the type of treatment administered. For instance, comparing the invasiveness for the patient, reoperation for intrathoracic anastomotic insufficiency cannot be equated with open revision of a neck wound or surgical opening of an infected surgical site. Thus, endoscopic procedures can be performed under sedation or general anesthesia, so caution is necessary when interpreting the Clavien-Dindo classification. [32].

We have never considered combining laparoscopy with open thoracotomy. In VATS lobectomies, it has been shown that a minimally invasive approach in the thorax offers a much greater advantage for the patient than a laparoscopy instead of a laparotomy [27].

We were able to reduce trauma by switching from a dorsal approach with five trocars to a ventral approach with three thoracocenteses. This made working caudally more comfortable, especially in the lower part of the thoracic esophagus. In all situations, even two instruments can be inserted through one opening. Nevertheless, in three cases it was necessary to cut out a window of the ribs to allow atraumatic removal of large tumors.

When the patient is positioned in a semi-prone position, the lungs are held out of the surgical field by gravity without touching or even grasping them [48].

The vitality of a sufficiently long conduit is crucial for anastomosis healing. This is why we have always chosen an open approach for the abdominal part of McKeown operations. This allows a more radical mobilization of the stomach and duodenum and probably leads to more centimeters of conduit length. This allows the anastomosis to be placed in a part of the conduit with a better blood supply. In addition, the conduit can be wrapped in a plastic sheet to protect the gastroepiploic vessels as it is pulled up to the neck. The tension of the conduit and the width of the hiatus can be digitally palpated. And as described above, laparoscopy is less advantageous postoperatively compared to thoracoscopy anyway [27].

The prophylactic placement of a jejunum catheter is still under discussion. However, it allows enteral feeding from the first postoperative day, which may be more physiologic, and has an overall low, but not zero, complication rate [49]. In one case, a superficial wound infection was treated only by removing the catheter. In another case, a displaced catheter led to a massive soft tissue infection with sepsis and multiple reoperations. Years later, two patients developed ileus due to adhesion of the jejunum to the left upper abdominal wall.

In some cases, we have stained the gastric tube with ICG before or after the anastomosis to avoid placing the anastomosis in a part of the stomach that is not well perfused. However, the use of ICG is associated with a learning curve as there is no quantification of blood flow [50–54]. Given the high rate of chylous fistulas, the intraoperative use of ICG to detect lymphatic drainage may be beneficial [55].

In addition to magnifying glasses, the use of a neurostimulator for the thoracic and cervical part is helpful in McKeown procedures. On the one hand, it helps to identify the recurrent laryngeal nerve, and on the other hand, it serves as a quality control after the creation of a cervical anastomosis. However, instruction by a thyroid surgeon is advisable to learn the handling and pitfalls of the neurostimulator [56, 57].

Our R0 resection rate of 100% was excellent, proving that locally advanced esophageal cancer is not a limit for minimally invasive surgery. In one case, the pericardium was partially resected due to suspected tumor infiltration;

in many other cases, parts of the pleura, lungs and diaphragm were resected.

In the past, a lymph node sampling of 15 nodes was considered sufficient. Based on better studies, it became clear that more than this number may be necessary [16]. Nowadays, it may be necessary to resect up to 30 lymph nodes. The quantity of lymph nodes present in patients varies, and there are constraints to consider regarding what is feasible and reasonable. At the very least, a high number of harvested nodes is also an indicator of the surgeon's significant level of proficiency.

It was a long learning process until we found a technique that met all our oncological and technical requirements. After all, minimally invasive resections are highly standardized, which enables a stable workflow within the entire team. All personnel involved must acquire the necessary skills to effectively manage these patients. This encompasses anesthetists, nurses, intensive care unit and ward nursing staff. Initially, this was improved through the distribution of clear guidelines and SOPs (Standard Operating Procedures).

Conclusions

Minimally invasive esophageal resections for cancer can be performed safely with generally acceptable perioperative and oncologic outcomes, even in low-volume institutions (< 30/year). Successful performance of this procedure requires the expertise of experienced surgeons with extensive training in minimally invasive thoracic surgery (VATS) and upper gastrointestinal surgery. It is recommended that a collaborative team-building process be carried out involving all relevant specialties. Furthermore, the evaluation of the results of the procedure proves to be beneficial [58]. However, prospective studies with standardized patient selection and long-term follow-up are still needed to evaluate the results of minimally invasive esophageal surgery.

Explanation of informed consent

Due to the analysis of retrospective, anonymized data, patient consent was waived.

Statement of the Institutional Review Board

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Medical University of Innsbruck (No.: 1186/2023).

Authors' contributions

Conceptualization, H.W. and P.G..; methodology, H.W.; validation: K.K-W., F.C.-B. and V.B.; data curation: A.P. and P.G.; writing, original draft preparation: H.W.; writing review and editing, H.W., A.S., P.G.; visualization, P.G.; supervision, T.S.; project administration: H.W., P.G.

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Data availability

The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request. Data are located in controlled access data storage at Medizinische Universität Innsbruck.

Declarations

Competing interests

The authors declare no competing interests.

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