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REVIEW

The Implementation of Minimally Invasive Surgery in the Treatment of Esophageal Cancer: A Step Toward Better Outcomes?

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ABSTRACT

Esophagectomy is considered the cornerstone of the radical treatment of esophageal cancer. In the past decades, minimally invasive techniques including robot-assisted approaches have become popular. The aim of minimally invasive surgery is to reduce the surgical trauma, resulting in faster recovery, reduction in complications, and better quality of life after surgery. Secondly, a more precise dissection may lead to better oncological outcomes. As such, minimally invasive esophagectomy is now seen by many as the standard surgical approach. However, evidence supporting this viewpoint is limited. This narrative review summarizes recent prospectively designed studies on minimally invasive esophagectomy.

Keywords: Esophageal cancer; Esophagectomy; Minimally invasive esophagectomy; Robotic esophagectomy

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Key Summary Points

Minimally invasive esophagectomy (MIE) and robot-assisted esophagectomy (RAMIE) are currently evolving worldwide.

The main advantages proven by randomized trials comparing open esophagectomy with MIE (hybrid or totally MIE) are fewer pulmonary complications and lower overall morbidity.

MIE and RAMIE provide oncologic outcomes that are at least equivalent to those of open esophagectomy.

The potential benefits of RAMIE over MIE remain to be identified in currently ongoing studies.

INTRODUCTION

Esophageal cancer is one of the most lethal malignancies worldwide. Early-stage esophageal tumors with infiltration limited to the mucosa and superficial submucosal layer meeting specific pathologic criteria are treated endoscopically, whereas locally advanced tumors usually require a multimodal approach including chemo(radio)therapy and surgery [1, 2]. That being said, esophagectomy is a complex operation associated with substantial morbidity; however, recent advances in surgical techniques aim to improve outcomes. Selection of patients who can tolerate esophagectomy and have the best chance of cure is also key. The selection process requires input from an experienced multidisciplinary team and preoperative tests to assess patients' comorbidities, frailty, and cardiorespiratory fitness.

The learning curve for esophageal resection is estimated to be around 100 procedures [3]. Although mastering the technical aspects is demanding, dealing with major complications is another challenging aspect in the training of young surgeons. This is supported by studies showing that the proficiency of the surgeon is associated with outcomes [4]. Registering and reporting data on surgical outcomes through national and international registries may also help to identify areas for improvement [5, 6]. However, morbidity has not improved to a great extent over the past decade, even in high-volume centers and despite centralization of treatment in reference centers in many countries [7]. Whether unit volume or individual surgeon volume is the most significant parameter in terms of optimal surgical results remains unclear.

Parallel to this, minimally invasive esophagectomy (MIE) has been taken up by many centers to reduce the surgical trauma. In fact, a diversity of hybrid and totally minimally invasive approaches has been reported, and most studies claim improvement in surgical results. A few randomized controlled trials (RCTs) have shown a reduction in morbidity, mainly in terms of pulmonary complications. Nevertheless, recently published retrospective cohort studies and studies looking at national registries have not been able to substantiate this perceived advantage of MIE. In fact, although reported pulmonary complication rates are lower, anastomotic leak rates are higher compared with the open techniques [8]. This observation underlines once again the complexity of the operation. Finally, quality of life after MIE beyond 3 months to 1 year is not clearly superior to open techniques according to some studies [9, 10]. Hence, the benefit of minimally invasive techniques outside RCTs remains unclear. Robotic-assisted minimally invasive esophagectomy (RAMIE) has also gained popularity by providing three-dimensional vision, precise surgical movements, and advanced ergonomics to the surgeon, and is currently being investigated with regard to perioperative and long-term postoperative outcomes.

This narrative review discusses the RCTs and large population-based cohort studies that investigated the efficacy of MIE, including RAMIE. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

RCTS ON MIE

Hybrid Esophagectomy

Hybrid esophagectomy is an operation whereby one stage of the operation is done in an open manner and the other part is minimally invasive. The MIRO study ran in 13 centers in France and compared open esophagectomy (open abdomen and open chest) with hybrid MIE (laparoscopy and open chest) for squamous cell carcinoma (84 patients) or adenocarcinoma (123 patients) [11]. Patients were randomly assigned to hybrid (103 patients) or open esophagectomy (104 patients). Randomization was performed on an institutional level. The study showed a 70% reduction in the chest infection rate in the MIE group [relative risk (RR) 0.30, 95% confidence interval (CI) 0.12–0.76]. However, 30-day postoperative mortality, intraoperative and 30-day postoperative overall morbidity (regardless of Clavien–Dindo grade), and overall surgical and medical morbidity (including operative time and median length of hospital stay) were similar between the two approaches. Mortality after open esophagectomy was 6% and 4% for MIE, which is rather high compared with international standards [6, 8]. Although the median length of hospital stay for both groups was

14 days, the range after open resections was wide (3–218 days versus 7–95 days for MIE). Criticism about the design of this study has been related to randomization, as it was institution- and surgeon-based rather than procedure-based, suggesting a possible impact of surgical skill, expertise, and, ultimately, surgeon's preference on the results presented in the study. Most importantly, a total of 207 patients from 12 centers were included, which might be considered a limited number of patients per center. Also, there were no data on the level of proficiency of the participating surgeons.

Another study, the ROMIO trial, investigates the outcome after MIE (hybrid with laparoscopy and open chest or total MIE) versus open esophagectomy in nine reference centers in the UK for esophageal adenocarcinoma or squamous cell cancer [12]. The protocol was published in 2001; patient recruitment has now been completed with a total of 526 patients, and the results are soon awaited [13]. The primary endpoint of the study was the short-term postoperative impairment of the physical status of patients using the EORTC QLQ-C30 questionnaire. The ROMIO trial is among the most well-designed studies in the field. Patients and assessors were blinded to the treatment. Also, surgical quality was evaluated after recording the resections included by the participating centers. The leading team reviewed and assessed the radicality of each of the resections (tumor resection and extent of lymphadenectomy). That being said, the methodology of this study, mainly in terms of establishing a pathway of quality assessment as a standard part of the design, might be a valuable example for future high-quality trials. However, once again, the diversity of the different incisions, the variety of the different minimally invasive techniques between the centers involved, the preference with regard to the site of anastomosis (neck, intrathoracic), and the perioperative management and protocols should be taken into consideration upon presentation of the final results.

The Austrian MOMIE trial was designed to compare open and hybrid Ivor Lewis esophagectomy. Two centers participated in the study, which aimed to investigate the differences between the two approaches in terms of morbidity and 30-day mortality as primary endpoints, and intensive care unit (ICU) stay, length of hospital stay, duration of operation, and survival as secondary endpoints [14]. However, the trial was terminated early owing to a high percentage of anastomotic leak (21.4%) in the MIE group (16 patients), resulting in the recruitment of only 26 patients in total. Morbidity, mortality, and oncological results in terms of 5-year survival rate and relapse-free survival were equivalent between the two groups. The unexpected results of this trial designed more than a decade ago reflect the consequences of an initial attempt to embrace and evaluate new techniques prior to widespread standardization and establishment of MIE.

Totally Minimally Invasive Esophagectomy

Quality of life after MIE (right thoracoscopy, laparoscopy with cervical or intrathoracic anastomosis) was compared with the open approach in another multicenter RCT (TIME trial) that started recruiting candidates for esophageal resection in 2009 [15, 16]. Five centers randomized 115 patients with esophageal cancer who underwent either open esophagectomy ($n = 56$) or MIE ($n = 59$). At 1-year follow-up, quality of life was significantly better after MIE in terms of physical recovery, general health status, and pain. Regarding the site of the anastomosis, a cervical anastomosis was performed in 66% of the patients in the open esophagectomy group and in 64% of the patients in the MIE group, resulting in a 39% and 44% rate of postoperative stenosis, respectively. Despite the statistical significance of the findings of this study, the number of patients per center was low for each arm, as all five centers performed a total of 56 open esophagectomies and 59 MIE. Despite the longer operating time for MIE (329 versus 299 min), MIE was associated with a lower percentage of respiratory complications (a reduction of 70%) during the first postoperative week, whereas anastomotic leak rate was similar in both approaches. Radicality between the two approaches was also comparable. That being said, disease-free survival and overall 3-year survival were also similar between MIE and open esophagectomy (42.9% and 37.3%, respectively, $p = 0.602$) (42.9% and 41.2%, respectively, $p = 0.633$). However, as in the MIRO study, patients and assessors were not blinded to the surgical approach, whereas the required inclusion criterion of "at least ten esophagectomies per center" is probably an inadequate level of expertise for an operation as technically demanding as esophagectomy.

RAMIE

With the aim of further minimizing surgical trauma and increasing the accuracy of surgical dissection, RAMIE has garnered interest as a promising approach in the surgical treatment of esophageal cancer. Advanced articulation of the robotic instruments, enhanced depth of the surgical view, and accurate manipulation of anatomic structures in a limited surgical space, during the abdominal and especially the thoracic part of the procedure, are reported among the main advantages of this evolving approach. RAMIE McKeown was introduced in 2006, and since then, it has been widely implemented in several departments in Europe, North America, and Asia [17].

In Europe, a Dutch study was one of the first case series reporting on patients who underwent RAMIE. That study was published more than a decade ago, reporting encouraging results during the initial phase of the learning curve [18]. In the ROBOT trial, 112 patients were randomized to open or robot-assisted three-stage esophagectomy with cervical anastomosis [19]. The primary endpoint was the rate of overall surgical complications. The oncologic outcome was equal between the two surgical options, while surgery-related postoperative complications, median blood loss, the rate of cardiopulmonary complications, and mean postoperative pain were significantly lower after RAMIE compared with open esophagectomy. Moreover, the short-term functional recovery and quality of life at discharge and 6 weeks after discharge were better in the RAMIE group. Interestingly, a follow-up study of the ROBOT trial also confirmed the long-term oncologic outcomes after RAMIE in terms of overall and disease-free survival, which were comparable to the open resection [20]. More precisely, with a median follow-up of 60 months, the combined 5-year overall survival rates for RAMIE and open esophagectomy were 41% and 40%, respectively ($p = 0.827$), while the 5-year disease-free survival rate was 42% and 43%, respectively, reflecting the non-inferiority in radicality of the robotic technique.

A recently published RCT from six high-volume Chinese centers randomized patients with squamous cell carcinoma to three-stage MIE or RAMIE for the period 2017–2019 [21]. The lymphadenectomy during RAMIE along the left recurrent laryngeal nerve was more meticulous and efficient compared with MIE (achievement rate 79.5% in RAMIE versus 67.6% in MIE, $p = 0.001$). At the same time, morbidity and mortality rates between the two approaches did not differ significantly. Interestingly, the total operative time was shorter in the RAMIE group. Long-term follow-up and survival rates are still awaited in 2022. One meta-analysis summarized the results of eight case–control studies and suggested that outcomes after RAMIE were similar to those after MIE [22]. In fact, this analysis investigated the rates of R0 resections and the total number of harvested lymph nodes in the specimens, finding no statistically significant differences between MIE and RAMIE. Overall, the robotic technique may have the potential to reduce the risk of laryngeal recurrent nerve injury when lymphadenectomy of the upper mediastinum is required. However, given that esophageal adenocarcinoma is the predominant histologic type in Western countries, an extended lymphadenectomy in the upper mediastinum along the laryngeal nerves is rarely applied for distal esophageal cancer. Nevertheless, the enhanced view and accurate dissection in the level of supracarinal/paratracheal lymph nodes provided by the robot could be promising.

A study from China randomized 144 patients to open esophagectomy or MIE [23]. Although the overall complication score was significantly lower in the MIE group, the rate of 55.3% for overall complications following MIE is considered high. Another multicenter RCT was designed to compare the 3-year outcomes between thoracoscopic esophagectomy and laparoscopic gastric mobilization with cervical anastomosis and open esophagectomy (right thoracotomy and laparotomy with cervical anastomosis) [24]. Thirteen hospitals in China are now actively recruiting patients after esophagectomy to primarily investigate the 30-day respiratory complications after surgery.

Two RCTs are currently recruiting patients eligible for MIE or RAMIE, aiming to evaluate the additional impact of RAMIE on surgical outcomes. Among them, the European ROBOT-2 RCT will include patients after either RAMIE or MIE for esophageal or junctional adenocarcinoma, with the primary endpoint being the extent of abdominal and thoracic lymph node dissection [25]. Furthermore, the REVATE trial is the first collaborative RCT between Europe and five Asian centers designed to clarify the rate of unsuccessful lymph node dissection along the left recurrent laryngeal nerve as a primary outcome. Number of successfully removed paratracheal lymph nodes, postoperative recovery, length of hospital stay, postoperative mortality, quality of life, and survival after RAMIE or MIE for esophageal squamous cell carcinoma are the secondary parameters that will be analyzed [26].

Table 1 summarizes the main characteristics and endpoints of the RCTs discussed in this review.

COHORT STUDIES OF MIE AND RAMIE

In addition to the existing evidence from previously published and ongoing RCTs, population-based studies aim to further enlighten the impact of MIE on postoperative results. A Dutch analysis extracted data from the national Dutch Upper GI Cancer Audit (DUCA) on 4605 patients who underwent transthoracic esophagectomy between 2011 and 2015 (1953 open versus 2652 MIE) [27]. Contrary to the previously presented results of the TIME trial, the DUCA dataset demonstrated increased total and respiratory complications and rate of reoperations in the MIE group. The length of hospital stay (1 day less for MIE) and the number of resected lymph nodes were in favor of MIE in the multivariate analysis. Overall, the results after the implementation of MIE in several centers in the Netherlands in 2010 and 2012 showed that a long learning curve is required to improve complication rates and surgical expertise.

Another population-based Dutch study collected data on 1727 patients after either open esophagectomy or MIE, and showed 62.6% overall complications in the first and 60.2% in the latter group [28]. Although pulmonary complications, R0 resection rate, and mortality rate did not differ significantly between the groups, again, anastomotic leak (15.5% versus 21.2%) and reintervention rates (21.1% versus 28.2%) were higher in the MIE group. Nevertheless, the median number of retrieved lymph nodes and median hospital stay were slightly better after MIE. This initiative was based on the DUCA collaboration in an effort to assess the impact of MIE among the reference centers in the Netherlands back in 2017.

Further prospective and retrospective studies have tried to elucidate the possible advantages of the new approaches and investigate the actual impact of MIE on surgical practice. However, the slow accrual of patients and the poor short-term outcomes in a few studies resulted in a reluctant audience within the esophageal surgical community. Such a retrospective American analysis compared 100 RAMIE cases with 625 MIE cases, finding no substantial differences in the short-term postoperative period [29]. Similarly, 19 retrospective studies were discussed in a systematic review and meta-analysis in 2021, and again, apart from the higher number of resected lymph nodes, MIE and RAMIE presented equal perioperative results [30].

Another aspect of the incorporation of RAMIE is the potential benefit of totally RAMIE over hybrid RAMIE. Either approach is being applied among different centers according to the surgeons' preference and expertise, and to date, no clear superiority of one technique over the other has been revealed. For example, a recent large multicenter German study analyzed

Table 1 List of recent and ongoing RCTs comparing the different approaches in esophagectomy

Name of trial	Period of data collection	Ongoing (O)/complete (C)	Country	Total number of patients	Surgical approaches		Primary endpoint	Key findings Hybrid (H)/open (O)/MIE
MIRO [11]	October 2009 to April 2012	C	France	207	Open: laparotomy, thoracotomy, intrathoracic anastomosis	Hybrid: laparoscopy, thoracotomy, intrathoracic anastomosis	Intraoperative/postoperative CDC $\geq$ II complications	Intraoperative/postoperative complication: H (36%)/O (64%) Pulmonary complication: H (18%)/O (30%)
ROMIO [12, 13]	October 2016 to September 2019	C	UK	478	Open: laparotomy, thoracotomy	Hybrid/MIE: laparoscopy, thoracotomy/thoracoscopy	Physical function scale (EORTC QLQ-C30) after surgery	Results awaited
MOMIE [14]	May 2010 to December 2012	Early closure	Austria	26	Open: laparotomy, thoracotomy, intrathoracic anastomosis	Hybrid: laparoscopy, thoracotomy, intrathoracic anastomosis	Morbidity (leak, conduit necrosis, pneumonia), mortality	Major complications: MIE (35.7%)/O (33.3%) Anastomotic leak: MIE (21.4%)/O (16.6%)
TIME [16]	June 2009 to March 2011	C	Netherlands, Spain, Italy	115	Open: laparotomy, thoracotomy, intrathoracic/cervical anastomosis	MIE: laparoscopy, thoracoscopy, intrathoracic/cervical anastomosis	Postoperative pulmonary infection	Short-term pulmonary infection: MIE (9%)/O (29%)
ROBOT-1 [19]	April 2012 to August 2016	C	Netherlands	109	Open: laparotomy, thoracotomy	RAMIE: Robot-assisted/ Thoraco-laparoscopic	Postoperative CDC $\geq$ II complications	Overall complications RAMIE (59%)/O (80%)
RAMIE [21]	July 2017 to December 2024 (a.a.)	O	China	360 (a.a.)	Totally MIE, Intrathoracic anastomosis, McKeown	Totally RAMIE, intrathoracic anastomosis, McKeown	5-Year overall survival	Ongoing follow-up before final results
Ma et al. [23]	July 2014 to October 2015	C	China	144	Open: laparotomy, thoracotomy	Totally MIE	CCI score after surgery	Overall complications MIE (55.3%)/O (86.6%) CCI mean (SD): MIE (13.07 $\pm$ 14.79)/O (19.16 $\pm$ 16.72); $p = 0.036$

Table 1 continued

Name of trial	Period of data collection	Ongoing (O)/complete (C)	Country	Total number of patients	Surgical approaches		Primary endpoint	Key findingsHybrid (H)/open (O)/MIE
Mu et al. [24]	September 2014, ongoing	O	China	648 (a.a.)	Open: laparotomy, thoracotomy, cervical anastomosis	Totally MIE: laparoscopy, thoracoscopy, cervical anastomosis	Respiratory complication after surgery	Recruiting
ROBOT-2 [25]	January 2021 to January 2028	O	Germany, Netherlands, Switzerland	218 (a.a.)	Totally MIE, Intrathoracic anastomosis	Totally RAMIE, intrathoracic anastomosis	Number of resected lymph nodes	Recruiting
REVATE [26]	October 2018 to December 2022 (a.a.)	O	China	190 (a.a.)	Hybrid: Thoracoscopy, Laparotomy/laparoscopy	Totally RAMIE	LND quality assessment	Recruiting

CDC Clavien–Dindo classification, *MIE* minimally invasive esophagectomy, *LND* lymph node dissection, *a.a.* as anticipated, *CCI* Comprehensive Complication Index

the surgical outcomes of the two robotic approaches and found that the 175 participants who underwent totally RAMIE benefited from lower risks of overall morbidity, anastomotic leak, and respiratory failure compared with 67 patients after hybrid esophagectomies [31].

DISCUSSION

The emergence of MIE and RAMIE in the treatment of esophageal cancer has shown some benefit for patients. Recent publications have presented promising results in terms of lower pulmonary complications compared with open approaches. In fact, avoiding thoracotomy might be a significant advantage of MIE and RAMIE, as the postoperative pain and physical impairment are better manageable after the minimally invasive approach according to some studies [32–34]. This may reduce the need for epidural analgesia, which results in some side effects. Quality of life in the short-term period after esophagectomy may also be better after MIE and RAMIE. That being said, identifying the studies that analyze the results of thoracoscopic or robot-assisted mobilization of the thoracic esophagus along with lymphadenectomy of the mediastinum rather than combining thoracotomy with laparoscopy—still considered as hybrid minimally invasive resections—is essential in understanding the impact of minimizing the surgical trauma in the thoracic phase of esophagectomy [35]. Herein, one could state that performing thoracotomy as hybrid minimally invasive resection prevents the benefits—if any—of thoracoscopy or robot-assisted thoracic dissection. This is a significant parameter that should be evaluated when interpreting the outcomes of the recent publication of the Esodata Study Group as well [36].

Interestingly, RAMIE, which is another technically demanding procedure, was also introduced to the esophageal surgical society over the same time period and evolved over the past two decades [37]. Throughout the years, most of the specialized centers around the world focused on mastering either MIE or RAMIE, as each approach requires a challenging learning curve. This institution-based approach resulted in a lack of direct comparison between the two novel techniques. More precisely, the high-volume centers aimed to transit directly from open esophagectomy to MIE or RAMIE. The sequelae of this approach could be a convincing explanation for the lack of data on the comparison between MIE and RAMIE as the learning curve of RAMIE is still in progress worldwide.

Among the most encouraging results of the previously presented RCTs is the evidence that the oncologic parameters R0 resection rate, number of lymph nodes retrieved, long-term survival, and disease-free survival rate were found non-inferior after MIE or RAMIE compared with the open approaches. Following the TIME study, which showed a trend toward improved 3-year survival after MIE—approximately 10% higher, $p = 0.207$—compared with the open approach, the ROBOT trial was one of the first studies that established the safety of RAMIE with regard to long-term oncological outcomes within a medium follow-up of 40 months [15, 16, 19]. Given that MIE and RAMIE are considered well-established techniques and are becoming the preferable approach in high-volume centers worldwide, the reasonable comparison that remains to be further investigated is the direct analysis of the long-term oncologic outcomes between MIE and RAMIE rather than their comparison with open resections. The RAMIE, ROBOT-2, and REVATE trials will enlighten this discussion in the future [21, 25, 26]. Hence, the enhanced view during abdominal and mediastinal laparoscopic, thoracoscopic, or robotic lymphadenectomy and the meticulous dissection regarding the primary tumor and the fields of lymphadenectomy have the potential to increase the number of resected lymph nodes, as clearly shown in previously published studies [27, 28, 30].

Although MIE and RAMIE have been embraced by many esophageal surgeons around the world with great enthusiasm, a few concerns remain regarding the true advantage of these techniques. On the basis of the limited number of existing and ongoing RCTs, we have witnessed the preliminary results of the technically demanding MIE and RAMIE following an undefined number of cases needed to establish the plateau of the learning curve. The number of patients that young trainees should operate on under supervision has been previously discussed but not agreed upon within the field of esophageal surgery [38]. Another parameter affecting the analysis of the surgical outcomes is the lack of standardization of the different resections. More precisely, both Ivor Lewis and McKeown esophagectomies are usually included in the studies, whereas the site of anastomosis (chest or neck), the various anastomotic techniques (hand-sewn, circular, or linear stapler), and the lack of an international consensus on the exact lymph node stations that need to be dissected en-bloc with the specimen are a few of the substantial issues encountered in the design and interpretation of the studies worldwide. Regarding perioperative management, a variety of enhanced-recovery protocols have been designed and implemented around the world; however, adherence to the different protocols is rarely reported in trial results, and these issues may interfere with the short-term outcomes after esophagectomy.

Another concern is the objective assessment of the postoperative complications, which remained scarce until recently (i.e., anastomotic leak, pulmonary complications). Lately, this has been addressed and refined through benchmarking and audits originating from high-volume centers and experts in the field [39–41]. Therefore, the implementation of common tools and strategies in the assessment of the postoperative results among the different centers can now be pursued and achieved. Standardization of the various surgical techniques, a common definition of complications, and a dedication to the challenging learning curve of MIE and RAMIE in a centralized fashion around the world have the potential to improve the outcomes. Before accomplishing these ambitions, similarly to the studies reporting on the lack of differences between the open and laparoscopic gastrectomy in the treatment of malignancy, paramount superiority of the new techniques is difficult to prove [42].

The results discussed in the present narrative review have previously been debated and argued in a few other reviews and meta-analyses. A recent meta-analysis reported improved intraoperative outcomes, lower morbidity rates, and more radical resections following RAMIE compared with MIE [43]. Both abdominal and mediastinal lymph node dissection seem to be superior after RAMIE, being more beneficial in the lymphadenectomy across the right laryngeal nerve [44]. Overall, what is clear among most of the reviews, including the present study, is that the intraoperative, perioperative, and overall clinical outcomes following MIE and RAMIE in high-volume centers are better compared with the open approach, whereas the long-term postoperative results of both MIE and RAMIE are at least equivalent [45].

From the MIRO to the ROBOT-2 trial, from Asian multicenter studies to international databases prospectively collecting data on patients with esophageal cancer, the comparison between different esophagectomies is being investigated in terms of short-term postoperative results and the oncologic impact of each resection [46, 47]. More precisely, intraoperative and postoperative complications, the impact of surgery on quality of life, and the oncologic outcome should be clearly addressed and standardized in future studies that aim to investigate the role of MIE and RAMIE in the current therapeutic landscape of esophageal malignancy. The Upper Gastrointestinal International Robotic Association (UGIRA) recently pursued the development of a consensus among representative experts on the field [48]. This initiative will hopefully guide surgeons through following appropriate indications for each approach, improving their technical experience and skills, and applying common perioperative pathways in the form of international guidelines and recommendations aiming to enhance the learning curve and achieve the safest and optimal surgical outcomes.

CONCLUSION

As the current evidence and objective results of the comparison between the open, MIE, RAMIE, and combined techniques based on prospectively designed studies remain scarce, there is a demand for larger studies. Building a strong theoretical and technical background and gradually incorporating new techniques and surgical skills should be achieved through intense training, fellowship programs, and proctorships. Furthermore, safe evaluation and constant assessment of the results seems to be the safe way to provide the optimal oncologic outcome for patients without compromising the surgical results of the global esophageal community.

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Compliance with Ethics Guidelines. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

Data Availability. 1. The datasets generated during and/or analyzed during the current study are available in the references' list. 2. All data generated or analyzed during this study are included in this published article/as supplementary information files. 3. Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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