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Worldwide techniques and outcomes in robot-assisted minimally invasive esophagectomy (RAMIE): results from the multicenter international registry

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<u>Authors' contributions</u>

The principal investigator of this study was RvH. The coordinating investigator was FK, who was also responsible for the analyses of this study. By means of repeated face-to-face Upper GI International Robotic Association (UGIRA) meetings and continuous digital interaction, all other authors contributed this work by: 1) substantial contributions the acquisition and interpretation of data; 2) participation in drafting the article and revising it critically for important intellectual content; and 3) final approval of the version to be published.

MINI ABSTRACT

Available evidence for robot-assisted minimally invasive esophagectomy (RAMIE) originates mainly from single center case series and one randomized trial, which may not be translatable to the international multicenter experience. This article provides the first real-world overview of the current techniques and outcomes of RAMIE in 20 international centers.

STRUCTURED ABSTRACT

Objective This international multicenter study by the Upper GI International Robotic Association (UGIRA) aimed to gain insight in current techniques and outcomes of RAMIE worldwide.

Background Current evidence for RAMIE originates from single-center studies, which may not be generalizable to the international multicenter experience.

Methods 20 centers from Europe, Asia, North-America, and South-America participated from 2016- 2019. Main endpoints included the surgical techniques, clinical outcomes, and early oncological results of RAMIE.

Results A total of 856 patients undergoing transthoracic RAMIE were included. Robotic surgery was applied for both the thoracic and abdominal phase (45%), only the thoracic phase (49%), or only the abdominal phase (6%). In most cases, the mediastinal lymphadenectomy included the low para-esophageal nodes (n=815, 95%), subcarinal nodes (n=774, 90%), and paratracheal nodes (n=537, 63%). When paratracheal lymphadenectomy was performed during an Ivor Lewis or a McKeown RAMIE procedure, recurrent laryngeal nerve injury occurred in 3% and 11% of patients, respectively. Circular stapled (52%), hand-sewn (30%), and linear stapled (18%) anastomotic techniques were used. In Ivor Lewis RAMIE, robot-assisted hand-sewing showed the highest anastomotic leakage rate (33%), while lower rates were observed with circular stapling (17%) and linear stapling (15%). In McKeown RAMIE, a hand-sewn anastomotic technique showed the highest leakage rate (26%), followed by linear stapling (18%) and circular stapling (6%).

Conclusion This study is the first to provide an overview of the current techniques and outcomes of transthoracic RAMIE worldwide. Although these results indicate high quality of the procedure, the optimal approach should be further defined.

INTRODUCTION

Curative treatment for esophageal cancer by means of esophagectomy achieves a 5-year survival rate of approximately 40-50% when it is preceded by neoadjuvant therapy (1,2). Esophagectomy is traditionally performed by an open approach that includes both a thoracotomy and a laparotomy (3). Aiming to reduce surgical trauma and decrease morbidity, minimally invasive esophagectomy (MIE) was adopted by many centers worldwide (4).

The TIME trial showed that MIE offers advantages over open esophagectomy in terms of blood loss, postoperative pain, postoperative pulmonary complications, and postoperative quality of life (5,6). However, conventional MIE is a complex procedure, as is demonstrated by an estimated learning curve of 20-175 procedures, mainly depending on the surgeon's experience and chosen parameters of proficiency (7). Results from nation-wide audits raised concerns regarding the safety, with a higher number of reinterventions being reported following MIE when compared to open esophagectomy (8-11). Some of the technical challenges of MIE, such as two-dimensional vision and restricted dexterity, can be overcome by using robotic assistance (12-14). Robot-assisted MIE (RAMIE) was introduced in 2003 and has repeatedly been shown to be feasible and safe (15-17). Moreover, the ROBOT trial showed that RAMIE was superior to open esophagectomy regarding blood loss, postoperative pain, pulmonary and cardiac complications, and functional recovery (18). Although the results of randomized controlled trials comparing RAMIE to MIE are still awaited (19,20), available evidence indicates that RAMIE is an excellent option to be used for esophageal cancer patients undergoing curative treatment (13,21,22). Nonetheless, esophageal resection remains a highly invasive procedure with substantial morbidity, even after RAMIE.

While RAMIE is gaining popularity, current literature mainly consists of single center studies with considerable variation regarding the exact surgical techniques. For example, while a hybrid RAMIE technique was initially reported by the pioneering center (robotic thoracic phase combined with a laparoscopic abdominal phase), there is an increasing adoption of a fully robotic approach (16,23,24). To gain insight in worldwide practice and ultimately identify the optimal RAMIE technique, an international multicenter collaboration was established by the Upper GI International Robotic Association (UGIRA). The current study aimed to gain insight in the current techniques and outcomes of RAMIE in these robotic centers worldwide.

METHODS

Patient population

The UGIRA was founded in 2017 by a multicontinental group of robotic surgeons, striving to facilitate the worldwide implementation and advancement of robotic esophagogastric surgery. To gain insight in outcomes and perform quality control, UGIRA established a comprehensive international registry for RAMIE in that same year. This registry has now been used for the first time to analyze the outcomes of patients who underwent transthoracic RAMIE for cancer between 2016-2019. Centers that were known to perform RAMIE were contacted in order to establish a consortium that represents worldwide practice. The following 20 centers participated in this study: University Medical Center Utrecht (The Netherlands), University Medical Center of the Johannes Gutenberg University (Germany), ZGT Almelo (the Netherlands), Chang Gung Memorial Hospital-Linko Chang Gung University (Taiwan), University of Cologne (Germany), University Pittsburgh Medical Center (USA), University Medical Center Groningen (The Netherlands), The Chinese University of Hong Kong (Hong Kong), Montpellier Cancer Institute (France), Universitätsklinikum Münster (Germany), University of São Paulo (Brazil), Universitätsklinikum Kiel (Germany), University Hospital Magdeburg (Germany), Amsterdam UMC (The Netherlands), University Hospital Eppendorf (Germany), Virginia Mason Hospital (USA), Charite University Medicine Berlin (Germany), Lancashire Teaching Hospitals (United Kingdom), The Royal Marsden (United Kingdom), and Città della Salute e della Scienza Università degli Studi di Torino (Italy). A minimum of 10 RAMIE cases had to be performed in order to be eligible for participation. Central institutional review board approval was obtained in the UMC Utrecht (17/837) and the local ethical approval was obtained in each center.

Outcomes and data collection

UGIRA Study Group consensus was reached regarding the essential registry items during an initial face-to-face meeting, which was followed by construction of a user-friendly online electronic case report form (eCRF) that captures the selected outcomes. The eCRF is accessible through the UGIRA website (https://www.ugira.org) and hosted by the epidemiology department of the UMC Utrecht. Data collection was partly retrospective (2016) and partly prospective (2017-2019). No personal details were collected in order to guarantee fully anonymous data collection, protecting patient privacy. Although this means that registered data could not be checked and revised at patient level, the quality of data was ensured by built-in validation checks. These checks were designed to prevent accidental skips and errors in completing the questionnaire by forcing the investigator to register all items or account for incomplete data before submitting a case. All data is encrypted and managed according to internationally accepted guidelines for an indeterminate time period. Data are accessible for the data managers and the coordinating investigator.

Centers were instructed to consecutively register their RAMIE cases. Collected demographic data include age, gender, body mass index (BMI), comorbidities, ASA score, tumor histology, clinical TNM stage, and type of neoadjuvant treatment. Surgical details of the RAMIE procedures, which were the primary outcomes of the current study, include the type of robotic system used, surgical approach, application of robotic surgery during distinct parts of the procedure (i.e. the thoracic and/or abdominal phases), patient positioning, type of reconstruction, anastomotic technique, extent of mediastinal lymphadenectomy, blood loss, operating time, intraoperative complications, and conversions to an open procedure. The occurrence of complications and severity of overall morbidity (Clavien-Dindo score) were collected in line with the Esophagectomy Complications Consensus Group agreements (25)). The specific grade of anastomotic leakage was not collected, since this outcome is partly determined by the type of initial treatment and the timing of resuming oral intake, which widely varied amongst the UGIRA centers depending on the individual postoperative care pathways. The UGIRA Study Group agreed to the following other key outcomes: length of stay on the intensive care unit and in the hospital, short-term mortality (i.e. during postoperative hospitalization or within 30 days after surgery), lymph node yield, and completeness of resection as defined by the College of American Pathologists (i.e. no tumor cells within the resection margins) (26).

Statistical analysis

All analyses were performed by using SPSS 25.0 (IBM Corp., Armonk, NY). Analyses were performed separately for two-stage Ivor Lewis and three-stage McKeown procedures. These groups were further divided in totally robotic (robotic thoracic and robotic abdominal phase) and hybrid robotic (robotic thoracic and laparoscopic abdominal phase) approaches. For each subgroup, the main endpoints were reported and the number of patients with textbook outcome was calculated. Textbook outcome was defined as: complete resection (R0), no intraoperative complications, a lymph node yield ≥15, no complications of Clavien-Dindo 3 or higher, no re-interventions, no readmission to the ICU, no length of hospital stay >21 days, no hospital readmission <30 days, no mortality <30 days, and no in hospital mortality (27). Continuous data were depicted as medians with ranges or means with standard deviations (SD), depending on data distribution. Categorical data were shown as frequencies with percentages (%) and their 95% confidence intervals (95%CI).

RESULTS

Patient demographics

During the inclusion period, a total of 874 patients who underwent RAMIE were registered by the 20 participating centers. After excluding 8 patients who underwent surgery because of benign disease and 10 robotic transhiatal esophagectomies, 856 transthoracic RAMIE procedures were included (682 from Europe, 95 from Asia, 56 from North-America, and 23 from South-America). The mean age was 63.5 years (SD ±10.5) and the mean BMI was 26.0 kg/m^2 (range 15.2-46.3 kg/m^2, SD ±4.8). The majority of patients were male (n=711, 83%), and nearly all patients had an ASA score ≥2 (n=793, 93%). Cardiovascular comorbidity was most common (n=393, 46%), followed by pulmonary comorbidity (n=144, 17%). Adenocarcinoma (n=581, 68%) and squamous cell carcinoma (n=253, 30%) were the most prevalent histological subtypes. Neoadjuvant therapy mostly involved chemoradiotherapy (n=556, 65%) or chemotherapy (n=164, 19%).

Surgical techniques and intraoperative results

RAMIE was conducted by a two-stage Ivor Lewis (n=622, 73%) or a three-stage McKeown approach (n=234, 27%) and **Table 1** shows the full details for each approach separately. Overall, robotic surgery was applied for both the thoracic and abdominal phase (n=386, 45%), only the thoracic phase (n=415, 49%), or only the abdominal phase (n=55, 6%). Conversion to an open procedure was required during the thoracic phase in 22 patients (3%) and during the abdominal procedure in 15 patients (2%). In most cases, mediastinal lymphadenectomy involved a dissection of the subcarinal nodes (n=774, 90%) and low para-esophageal nodes (n=815, 95%). High mediastinal dissection along the recurrent laryngeal nerves was performed in over half of cases (n=537, 63%).

Postoperative outcomes

In the total of 856 RAMIE procedures, postoperative complications occurred in 512 cases (60%), a complete resection (R0) was achieved in 801 cases (94%), the median lymph node yield was 28 nodes [0-89], and short-term mortality was reported in 26 cases (3%). The perioperative details are shown separately for totally robotic (robotic thoracic phase combined with a robotic abdominal phase) and hybrid robotic (robotic thoracic phase combined with conventional laparoscopy) Ivor Lewis and McKeown procedures in **Table 2**. The overall rate of textbook outcome was 41% with a range of 40-43% amongst the specific subgroups. In patients undergoing Ivor Lewis esophagectomy with use of the robot during at least the thoracic phase (n=568), recurrent laryngeal nerve (RLN) injury occurred in 9 out of 307 patients who underwent paratracheal lymphadenectomy (2%) while no RLN injury was reported in the 261 patients who did not undergo paratracheal lymphadenectomy (0%). In patients undergoing McKeown esophagectomy with use of the robot during at least the thoracic phase, RLN injury occurred in 23 out of 206 patients who underwent paratracheal lymphadenectomy (11%) and in 2 out of 27 patients who did not undergo this dissection (7%). The leakage rate of each anastomotic technique is presented in **Table 3**.

DISCUSSION

This is the first study to report clinical and short-term oncological results of RAME in a large, worldwide, multicenter setting. Variations were mainly found regarding the application of robotic surgery during the thoracic and abdominal phase, the anastomotic technique, and the extent of mediastinal lymphadenectomy. The overall postoperative complication rate was 60% and mortality occurred in 3% (in-hospital or within 30 days after surgery). Furthermore, a median lymph node yield of 28 nodes was found and a complete resection was achieved in 94% of cases. Textbook outcome was attained in 41% of patients undergoing RAMIE and the outcomes of totally robotic and hybrid robotic procedures seemed to be similar.

RAMIE versus conventional MIE

The current study shows that RAMIE is associated with good overall perioperative results and an overall textbook outcome rate of 41%, which is higher than the average of 30% that was reported by a previous study that mostly included open and conventional minimally invasive esophagectomies from the Dutch national database between 2011-2014 (27). With regard to the individual clinical and oncological outcomes such as complications and completeness of resection rate, the current results are in line with recently published international benchmarking studies on esophagectomy (28-29). Although RAMIE is a relatively novel technique, this registry shows that the outcomes are already similar to those of the ECCG consortium, which consists of expert esophageal cancer treatment centers (28). This is an important observation, as it confirms the high quality of data and feasibility of using the ECCG definitions to collect and report multicenter outcomes for esophagectomy in a standardized and reproducible way.

The current outcomes of RAMIE in terms of postoperative complications and lymph node yield seem to be comparable to previous benchmarks that were established for conventional MIE (28). This is particularly interesting when realizing that this previous study only included esophageal cancer patients that were classified as being ‘low risk’, while the current study reported real-world outcomes for the overall patient population undergoing RAMIE. While these positive findings for RAMIE are promising, it should be noted that the prior benchmarking study included an older cohort (years 2011-2016) than the current study (years 2016-2019), hampering a head-to-head comparison. Enhanced recovery after surgery (ERAS) protocols for esophagectomy have been increasingly implemented over the last years, as they were shown to be effective in accelerating recovery (30-32). However, the median length of ICU and hospital stay were still 2 and 13 days in this study, respectively. As ERAS principles were not uniformly applied amongst the UGIRA centers, the current outcomes seem to highlight the importance of ERAS in optimizing the outcomes of RAMIE.

Considering that the currently presented data were partly collected from centers that were still in their learning curve, the outcomes of RAMIE are expected to improve. To avoid the initial problems of conventional MIE that were reported in terms of re-intervention rates, effective training and an adequate case volume are crucial (8-11). In this context, UGIRA has established a structured training pathway for RAMIE, which has been found to be safe and effective for centers that are wanting to implement this technique (33). This training pathway is now recommended by UGIRA and will be further optimized based on other surgeons' experiences. In addition to improving training, multicenter comparisons of RAMIE to other techniques will be needed in the near future. At present, surgeons generally switch to RAMIE because of their personal believe that robotic surgery improves their procedure and ergonomics. However, the currently presented data indicate that the clinical benefits of RAMIE over MIE remain to be elucidated. Several studies showed that the learning curve of RAMIE is about 24 cases when a structured training pathway is followed by surgeons who are experienced in MIE, which is relatively short (33,34). The technical advantages of robotic surgery (i.e. three-dimensional vision, tremor filtration, increased dexterity) most probably contribute to a short learning curve. For experienced robotic surgeons, particular benefits are exhibited in the most challenging cases, such as salvage esophagectomy or the resection of tumors and lymph nodes metastases located near the upper thoracic inlet (35). Furthermore, lymphadenectomy along the recurrent laryngeal nerves may be facilitated, although RLN injury rates of 3% and 11% were still found after upper mediastinal dissection during RAMIE by an Ivor Lewis and McKeown approach, respectively. While this difference might be explained by the cervicotomy that is part of a McKeown procedure, it could also be possible that paratracheal lymphadenectomy was performed more extensively in patients who underwent McKeown esophagectomy in this cohort. To elevate the overall outcomes of RAMIE over MIE, technological developments such as augmented reality may be crucial, as this technology will increasingly be brought to robotic systems to facilitate training or even allow surgical navigation (36,37).

Anastomotic technique

Although the outcomes of RAMIE were generally good in this study, the anastomotic leakage rate was relatively high in relation to previous findings in literature. This seems to be mainly explained by an aggregate leakage rate of 33% in a large subgroup of patients who underwent RAMIE with a hand-sewn intrathoracic anastomosis, suggesting that a stapled anastomosis achieves better outcomes within the current dataset. However, several centers switched directly from a cervical to a robotic hand-sewn intrathoracic anastomosis during this study and most subsequently changed to a stapled technique due to unsatisfying initial outcomes of hand-sewing. Hence, the current results should be interpreted in the context of a developing technique and learning curve.

Irrespective of the exact technique, the overall learning curve of RAMIE has been reported to plateau after 80 cases and a previous study found that 119 cases may be required to reach anastomotic proficiency when adopting an intrathoracic anastomosis (34,38-41). Only 5 centers included more than 80 RAMIE procedures at the end of the inclusion phase, of which only 1 had completed their learning curve before starting inclusion. Moreover, none of the participating centers had performed this number of robotic hand-sewn anastomoses at the time of analyses. As most centers are still in their learning curve for RAMIE, we are still in an early stage of global adaptation. It is too early to differentiate between a learning curve effect and a true difference in technique-related outcomes. The lack of tactile feedback in robotic surgery can be challenging during the learning curve, as the gastric conduit is easily harmed by manipulation during construction of the anastomosis. This is one of the reasons why experienced robotic surgeons avoid grasping the tissue, and rather bluntly lift or retract.

Further research should clarify whether a robotic hand-sewn technique can achieve similar leakage rates as stapling. This might be aided by intraoperative near-infrared imaging by means of Firefly technology to assess conduit perfusion technology, which could not be evaluated in this study. In addition, future studies need to clarify whether the duration of the required learning curve for this anastomotic technique is acceptable.

Previous meta-analyses comparing hand-sewn versus stapling techniques never found convincing evidence to support the possible idea that a stapled technique is associated with lower leakage rates after esophagectomy (14,42,43). Although a manual anastomosis offers the surgeon maximal control over the reconstruction procedure, suturing is challenging during conventional thoracoscopy, leading many surgeons to perform a mechanical anastomosis during conventional MIE. Robotic instruments provide greater dexterity, facilitating manual suturing. While a hand-sewn anastomosis requires the most extensive manual suturing, it should be noted that some suturing is also needed when constructing a mechanical anastomosis (i.e. a purse-string suture for a circular stapled anastomosis and a running suture to close part of the circumference for a linear stapled anastomosis). In this light, robotic assistance may aid the construction of all types of anastomoses.

Strengths and limitations

This study derives particular strength from its international multicenter design. The participating centers were selected from all parts of the world. Although not all known RAMIE centers contributed their data, this study established a representative overview of current real-world practice in RAMIE. The data collection was performed through a specifically developed online eCRF, which included perioperative variables that were meticulously chosen based on UGIRA Study Group consensus and ECCG agreements (25). These essential steps ensured the standardized high-quality data collection, which is a prerequisite for multicenter studies of this kind. However, this study also has limitations. For the sake of feasibility, the RAMIE registry collects data with a limited level of detail and length of follow-up. Therefore, no analyses could be performed for the severity of each separate complication, lymph node yield per station, or survival.

Conclusions

Totally robotic and hybrid RAMIE are associated with good clinical and short-term oncological results. Variations in technique were mainly found regarding the use of robotic surgery during the thoracic and abdominal phase, anastomotic technique, and extent of lymphadenectomy. A relatively high leakage rate was observed with a robotic hand-sewn intrathoracic anastomosis. Although these results are encouraging, the optimal technique needs to be further defined based on the current findings.

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Table 1. Characteristics of the transthoracic RAMIE procedures (n=856)

	Ivor Lewis (n=622)		McKeown (n=234)	
	n	(%)	n	(%)
Continent				
Europe	569	(91)	113	(48)
North-America	53	(9)	3	(1)
Asia	0	(0)	95	(41)
South-America	0	(0)	23	(10)
Clinical T stage				
cTx/unknown	18	(3)	1	(0)
cT1	42	(7)	20	(9)
cT2	112	(18)	53	(23)
cT3	426	(69)	145	(62)
cT4	24	(4)	15	(6)
Clinical N stage				
cNx/unknown	16	(3)	1	(0)
cN0	195	(31)	69	(30)
cN1	326	(52)	81	(35)
cN2	75	(12)	68	(29)
cN3	10	(2)	15	(6)
Robotic system				
Da Vinci Xi	458	(74)	154	(66)
Da Vinci Si	153	(24)	80	(34)
Da Vinci X	11	(2)	0	(0)
Use of robot				
Robot thorax + robot abdomen	331	(54)	55	(24)
Robot thorax + laparoscopy	207	(33)	152	(65)
Robot thorax + laparotomy	30	(5)	26	(11)
Robot abdomen + thoracoscopy	27	(4)	1	(0)
Robot abdomen + thoracotomy	27	(4)	0	(0)
Patient positioning during thoracic phase				
Semiprone	445	(72)	220	(94)
Left lateral decubitus	154	(25)	12	(5)
Prone	22	(3)	2	(1)
Other	1	(0)	0	(0)
Mediastinal lymphadenectomy				
High – paratracheal nodes	330	(53)	207	(89)
Mid – subcarinal nodes	541	(87)	233	(100)
Low – para-esophageal nodes	588	(95)	227	(97)
Reconstruction technique				
Gastric conduit	621	(100)	230	(98)
Colon interposition	1	(0)	2	(1)
None	0	(0)	2	(1)
Anastomotic type				
End-to-Side	484	(78)	151	(64)
End-to-End	58	(13)	16	(7)
Side-to-Side	80	(9)	65	(28)
NA (no primary reconstruction)	0	(0)	2	(1)
Anastomotic technique				
Circular stapled	379	(61)	64	(27)
Hand-sewn	151	(24)	102	(44)
Linear stapled	92	(15)	66	(28)
NA (no primary reconstruction)	0	(0)	2	(1)

Table 2. **Perioperative clinical and pathological outcomes in totally robotic (robot thorax + robot abdomen) or hybrid robotic (robot thorax + laparoscopy) RAMIE (n=745)**

	Ivor Lewis (n=538)		McKeown (n=207)	
	Totally robotic (n=331)	**Hybrid robotic (n=207)**	**Totally robotic (n=55)**	**Hybrid robotic (n=152)**
Textbook outcome#	141 (43%)	85 (41%)	22 (40%)	60 (40%)
Operative time, median minutes [range]	400 [264-790]	433 [134-1017]	421 [323-682]	435 [193-783]
Blood loss, median mL [range]	100 [10-800]	200 [20-1600]	100 [50-1000]	100 [5-900]
Postoperative complications				
Any	174 (53%)	139 (67%)	41 (75%)	97 (64%)
Pulmonary (including pneumonia)	77 (23%)	67 (32%)	21 (38%)	51 (34%)
Anastomotic leakage	65 (20%)	53 (26%)	12 (22%)	27 (18%)
Cardiac (including atrial fibrillation)	50 (15%)	20 (10%)	7 (13%)	14 (9%)
Recurrent laryngeal nerve injury	3 (1%)	6 (3%)	5 (9%)	17 (11%)
Chyle leakage	16 (5%)	12 (6%)	2 (4%)	8 (5%)
Wound infection	4 (1%)	1 (1%)	0 (0%)	5 (3%)
Clavien-Dindo of most severe complication				
0 (No complication)	157 (47%)	68 (33%)	14 (26%)	55 (36%)
1	10 (3%)	15 (7%)	13 (24%)	18 (12%)
2	65 (20%)	31 (15%)	12 (22%)	28 (18%)
3a	39 (12%)	51 (25%)	3 (6%)	18 (12%)
3b	26 (8%)	21 (10%)	2 (4%)	16 (11%)
4	26 (8%)	17 (8%)	9 (16%)	16 (11%)
5	8 (2%)	4 (2%)	2 (4%)	1 (1%)
Length of stay				
ICU / MCU stay, median days [range]	2 [0-112]	3 [0-112]	4 [1-84]	1 [1-106]
Hospital stay, median days [range]	12 [6-118]	15 [5-168]	13 [8-92]	13 [5-124]
Postoperative mortality^	10 (3%)	6 (3%)	3 (6%)	3 (2%)
Lymph node yield				
Total, median number [range]	28 [3-81]	29 [8-70]	27 [11-71]	28 [4-89]
Tumor-positive, median number [range]	0 [0-33]	0 [0-34]	0 [0-33]	0 [0-13]
R0 resection*	313 (95%)	195 (94%)	51 (93%)	141 (93%)

Definition: complete resection (R0), no intraoperative complications, a lymph node yield □15, no complications of Clavien-Dindo 3 or higher, no re-interventions, no readmission to the ICU, no length of hospital stay >21 days, no hospital readmission <30 days, no mortality <30 days, and no in hospital mortality

^ Refers to mortality that occurred due to any cause during postoperative hospitalization or within 30 days after esophagectomy

* Refers to R0 as defined by the College of American Pathologists (i.e. absence of malignant cells within the resection margins)

95% CI; 95% confidence interval, NA; not applicable, ICU; intensive care unit, MCU; medium care unit

Table 3. Anastomotic techniques and associated leakage rates in RAMIE (n=856)

		Anastomotic leakage	
		n	**(%)**
Ivor Lewis (n=622)			
Circular stapled intrathoracic anastomosis	(n=315)	64	(17)
Linear stapled intrathoracic anastomosis	(n=92)	14	(15)
Hand-sewn intrathoracic anastomosis	(n=151)	49	(33)
McKeown (n=234)			
Circular stapled cervical anastomosis	(n=64)	4	(6)
Linear stapled cervical anastomosis	(n=66)	12	(18)
Hand-sewn cervical anastomosis	(n=102)	27	(27)