Intrathoracic anastomotic techniques in robotic assisted minimally invasive esophagectomy: a narrative review

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Background and Objective: Robotic assisted minimally invasive esophagectomy (RAMIE) has seen a considerable expansion in adoption with significant variations in technique. Technical variations in creating anastomoses are no exception, and several routinely employed methods have been described for these procedures. The objective of this narrative review is to familiarize surgeons interested in robotic esophageal surgery with these techniques.

Methods: Relevant publications were retrieved using targeted searches of Medline. This literature and my own practices as an experienced robotic thoracic surgeon were reviewed.

Key Content and Findings: The types of anastomoses most commonly created by the majority of surgeons include circular stapled, linear stapled, and handsewn. It is important for surgeons performing RAMIE to understand these technical variations and specific ramifications to the learning curve, as well as complications, such as anastomotic leak and stricture, potentially inherent to each approach. The major anastomotic techniques employed during RAMIE are discussed, as well as data regarding outcomes and complications specific to the individual methods.

Conclusions: Data regarding the "best" anastomotic technique for robotic-assisted esophagectomy is very much in evolution. The circular-stapled method may be the most comfortable to adopt at the outset, although linear-stapled and handsewn anastomoses grant the surgeon the ability to perform a completely robotic assisted anastomosis under direct control.

Keywords: Robotic esophagectomy; robotic surgery; esophageal cancer; esophageal anastomosis; robotic assisted minimally invasive esophagectomy (RAMIE)

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Introduction

Robotic assisted minimally invasive esophagectomy (RAMIE) is being increasingly utilized in the United States and worldwide, with several variations of the technique described by surgeons from many different institutions (1-3). Similar to non-robotic minimally invasive esophagectomy (MIE) or open esophagectomy, technical aspects of anastomosis creation during RAMIE can vary significantly among surgeons (4). Regardless of the technique employed, the principal tenets of creating a tension-free, well-vascularized, and widely patent anastomosis with adequate tumor resection margins remain crucial. Adherence to these key elements will optimally attenuate the risk of leak or stricture, which remain significant sources of morbidity after esophagectomy (5).

A few factors are considered when describing anastomoses created during esophagectomy. The first is location, whether intrathoracic or cervical. The second is the type of conduit used to re-establish gastrointestinal continuity. This is most commonly the stomach, but jejunum or colon can also be used. The third is the specific technique used to create the anastomosis, which broadly falls into three major categories:

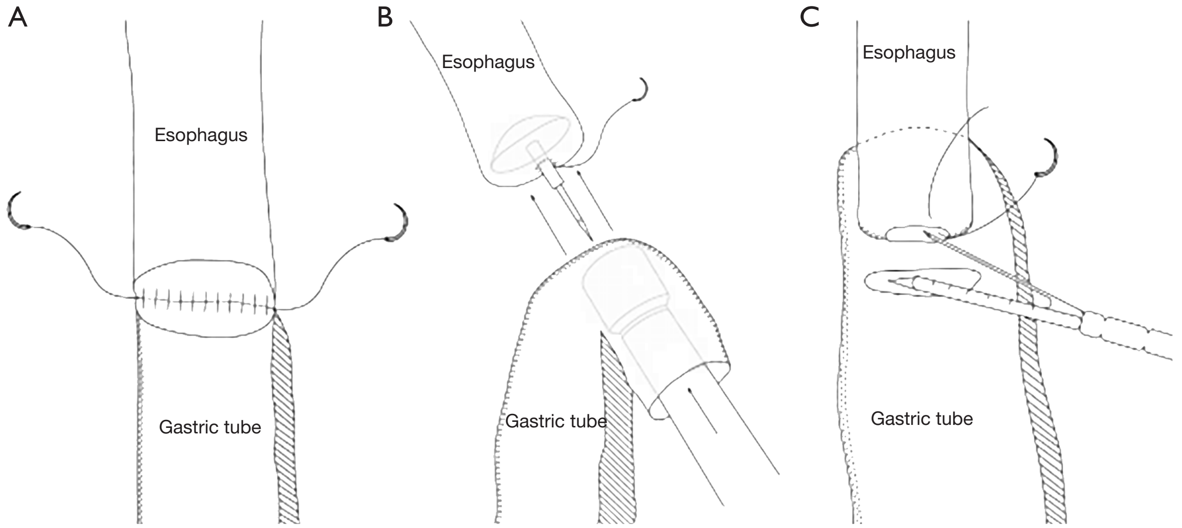

Figure 1 Types of intrathoracic anastomoses commonly performed during robotic assisted minimally invasive esophagectomy (RAMIE) using the stomach as a conduit. (A) Handsewn; (B) circular stapled; (C) linear stapled. Reprinted with permission from Elsevier from Plat *et al.* (6).

circular stapled, handsewn, or linear stapled (*Figure 1*). The specific anatomic positioning of the esophagus and the conduit, whether end-to-end, end-to-side, or side-to-side, can also be considered a component of the mechanical technique employed to create the anastomosis. This review will focus on intrathoracic gastroesophageal anastomoses created during RAMIE operations using the stomach as a conduit created using either circular-stapled, handsewn, or linear-stapled techniques (*Figure 1*). The objective of this narrative review is to familiarize surgeons interested in robotic esophageal surgery with these anastomotic techniques. While inclusion of every subtle variation and nuance of these procedures is beyond the scope of this review, the major anastomotic techniques employed during RAMIE are discussed, as well as data regarding outcomes and complications specific to the individual methods. I present this article in accordance with the Narrative Review reporting checklist (available at https://aoe.amegroups.com/article/view/10.21037/aoe-22-2/rc).

Methods

I performed PubMed searches using the following keywords: robotic esophagectomy, robotic surgery, esophageal cancer, esophageal anastomosis, and robotic assisted minimally invasive esophagectomy. All articles in English published from January 1, 2000 through December 31, 2021 were surveyed to elaborate on this manuscript. Series from experienced centers, meta-analyses, and multicenter studies were prioritized and read in full. I also reviewed my personal practices as a highly experienced robotic thoracic surgeon and a well-established instructor of robotic thoracic surgery (*Table 1*).

Narrative

Circular-stapled anastomoses

The basic sequence of creating a circular-stapled anastomosis is relatively straightforward and reproducible (*Figure 2*). The end-to-end anastomotic (EEA) stapler is manufactured by Medtronic, Inc in several sizes ranging most commonly from 25 to 33 mm. The circular-stapled anastomosis requires placement of an anvil within the esophagus, and placement of the circular stapler itself within the conduit. A 4-cm access incision and a skilled bedside assistant are necessary to position and fire the stapler. Once joined, the stapler creates the anastomosis by first approximating the anvil to the housing of the stapler and mechanically affixing the adjoining tissues with full thickness deployment of the staples. The core of central tissue is cut and excised to create the common passage between the gastric conduit and esophagus and is represented by the gastric and esophageal anastomotic rings of tissue remaining on the stem of the anvil. If incomplete rings are observed, the mechanical integrity of the anastomoses must be assumed to be compromised. While

Table 1 The search strategy summary

Items	Specification
Date of search	January 15, 2022
Databases and other sources searched	PubMed/Medline
Search terms used	robotic esophagectomy; robotic surgery; esophageal cancer; esophageal anastomosis; robotic assisted minimally invasive esophagectomy
Timeframe	2000 to 2021
Inclusion and exclusion criteria	Inclusion: English language; Exclusion: Animal studies
Selection process	Performed by author I.S.S., MD
Any additional considerations, if applicable	Series from experienced centers, meta-analysis and multicenter studies were prioritized; author also retrieved additional publications that he was familiar with as an expert minimally invasive thoracic surgeon

the technical execution of this procedure actually creates an end-to-side anastomosis, the anastomosis is functionally an end-to-end anastomosis in most descriptions of the technique with very little or no proximal conduit remaining after completion.

When performing a circular-stapled anastomosis, placement of the anvil is often accomplished with a robotically handsewn purse-string suture. Alternatives include placement of the purse-string suture with an automated device or affixing the OrVil 25 mm EEA stapler (Medtronic, Inc.) to a nasogastric tube that is brought through the oropharynx. This method may obviate the need for a purse-string suture if the esophagus is transected with a stapler. Possible drawbacks of this method include the close apposition of these staple lines, as well as being limited to a smaller 25-mm anvil, with the potential for higher rates of stenosis as compared with larger sizes available for the standard stapler.

Table 2 summarizes several reports on circular-stapled anastomoses that included 10 or more patients. There was relatively varied distribution in the size of anvil used, ranging from 25 to 29 mm. Anastomotic leak rates ranged widely from 0% to 20%, with most reporting anastomotic leak rates of 5–10%. Rates of stenosis/stricture requiring dilation are less frequently reported. Only two of the reports note stenoses requiring dilation. In this author's own published experience in an initial cohort of 89 patients, 3% required dilation, while Wang and colleagues reported a 7% incidence of dilation and an overall stricture rate of 19% (8,16). One study reported a 17% rate of postoperative dysphagia although details of this were not clearly stated (13).

Linear-stapled anastomosis

The basic sequence of creating the linear-stapled anastomosis is first affixing the conduit and esophagus side to side with significant overlap. The degree of overlap of the esophagus on the gastric conduit will largely determine the extent of the anastomotic orifice created. Each time of the linear stapler is introduced into either the gastric or esophageal lumen through a small fenestration, and single fire is applied to create a common channel between the two. The smaller common defect can then be closed either via stapling or by handsewn techniques at the discretion of the surgeon (*Figures 3,4*). These may include single- or two-layer closures, multiple single or running sutures, degradable or permanent suture, and use of self-locking barbed sutures. Given the combined stapled and sewn aspect of many of these techniques, the term "hybrid" has been commonly adopted for linear-stapled anastomotic closures. An advantage of this technique is that it is likely the most simple and expeditious to execute. One potential critique of the linear-stapled anastomosis is the potential to sacrifice additional margin to create the necessary side-to-side apposition of the 2 lumens. However, no studies have reported specifically on differences in margin lengths or recurrence rates between anastomotic techniques.

Table 3 summarizes several studies that included 10 or more patients with linear-stapled (hybrid) anastomoses. Anastomotic leak rates after robotic linear stapling were relatively uniform, ranging from 4% to 8%, with rates of stenosis ranging from 6% to 16%. Rates of stenosis requiring dilation were not specifically addressed.

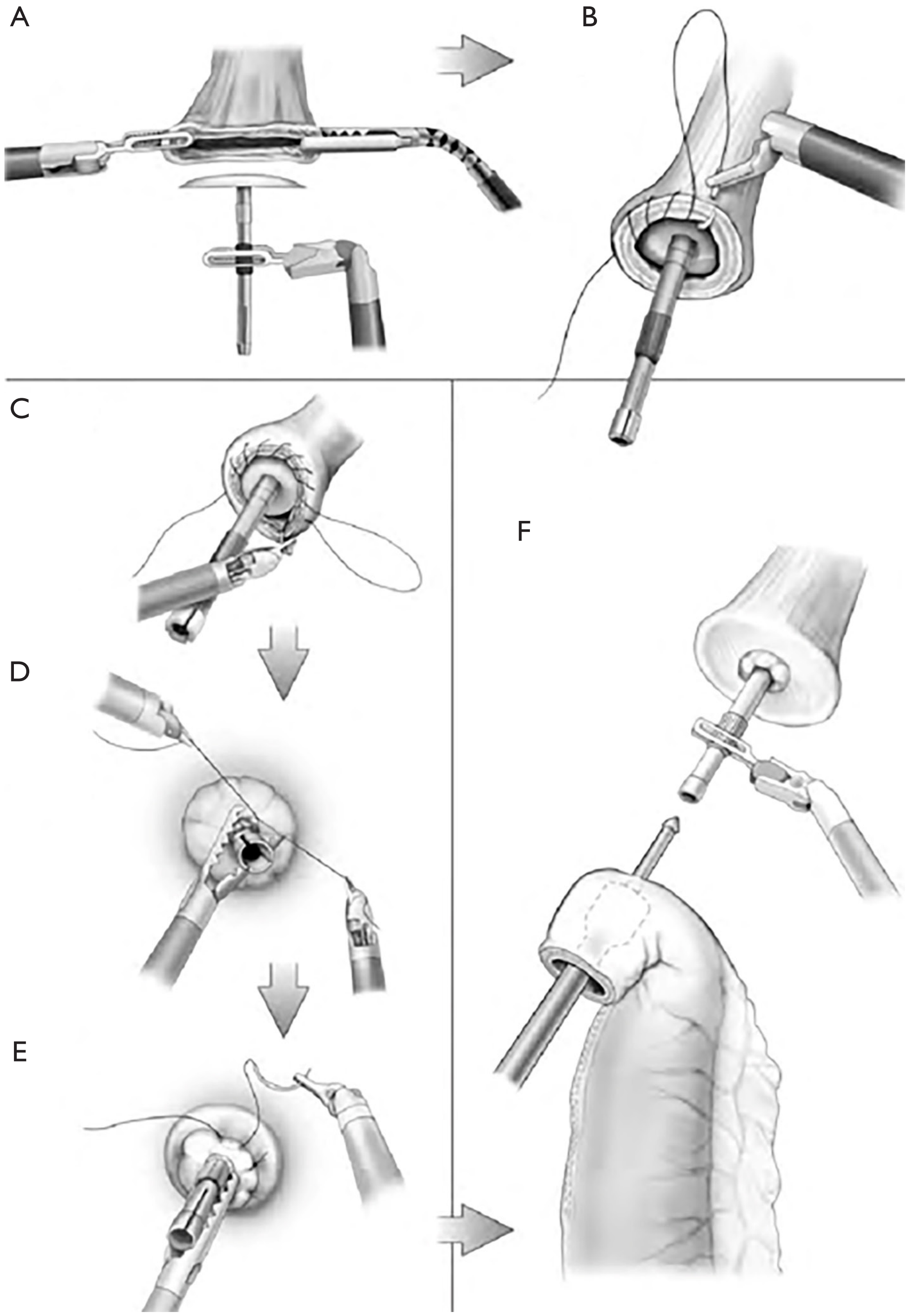

Figure 2 Circular-stapled technique during robotic-assisted minimally invasive esophagectomy using a "purse-string" technique. (A) Placement of the stapler anvil in the esophagus. (B-E) Securing the anvil with purse-string sutures. (F) Placement of the EEA stapler in the gastric conduit. Reprinted with permission from Sarkaria *et al*. (7).

Handsewn anastomosis

"Handsewn" anastomoses are those created with suture only and no mechanical device. The robotic platform has greatly aided in the ability to sew intracorporeally as compared with standard laparoscopic or thoracoscopic techniques (*Figure 5*). Techniques vary in ways that are similar to the different handsewn techniques used for anastomosis during open surgery. Points of variation include the orientation (side to

Table 2 Descriptive studies of the circular-stapled anastomotic technique with 10 or more patients

Authors	Year	Number	Size	Leak rate	Stricture	30-day mortality	90-day mortality
Sarkaria (8)	2016	89	29 mm	6%	3%	0%	1%
Wee (9)	2016	20	25 mm, 28 mm	0%	NR	0%	0%
Okusanya (10)	2017	23	28 mm	4%	NR	0%	0%
Meredith (11)	2018	147	25 mm OrVil	3%	NR	0.7%	1.4%
Zhang (12)	2018	35	25 mm	11%	NR	0%	NR
Zhang (13)	2019	42	25mm	4.8%	16.7% (post-op dysphagia)	0%	NR
Pötscher (14)	2019	10	25 mm OrVil	20%	NR	NR	NR
Tagkalos (15)	2019	50	25 mm, 28 mm	12%	NR	0%	4%
Wang (16)	2019	31	25 mm	6%	19% (7% requiring dilation)	0%	NR
de Groot (17)	2020	60	29 mm	17% (5% grade 3)	NR	NR	
Pointer (18)	2020	350	25 mm OrVil	15.7% (2% requiring operation)	NR	2.6%	NR
van der Sluis (19)	2021	100	25 mm, 28 mm	8%		1%	3%

NR, not reported; post-op, postoperative.

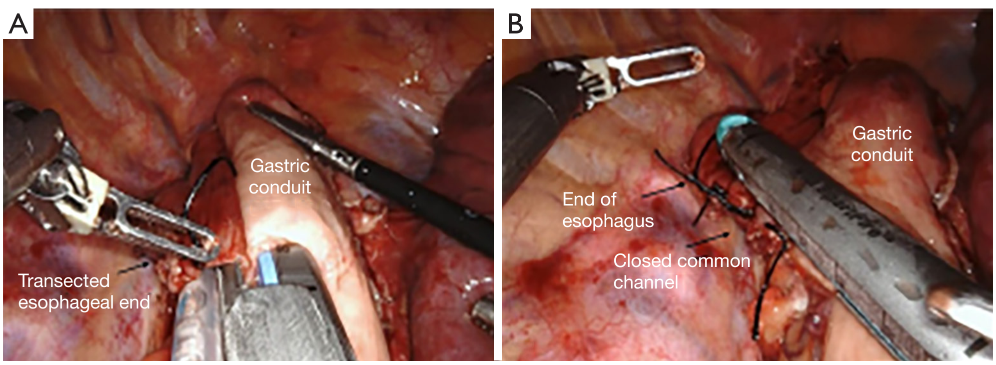

Figure 3 Linear-stapled technique with stapled closure of anterior defect. (A) Creation of the esophago-gastrotomy. (B) Closure of the common channel. Reprinted with permission from Chouliaras *et al.* (20).

side, end to side, end to end), one- or two-layer closure, and type and number of sutures used. The surgeon must take care to avoid purse-stringing the anastomosis closed if a single running suture is used to complete an entire circular anastomosis. It is advisable to use multiple running sutures fixed at 2–3 points to avoid iatrogenic stenoses. Handsewn anastomoses are generally more time consuming to construct than stapled anastomoses but are entirely within the hands of the console surgeon.

Table 4 summarizes studies reporting outcomes of RAMIE with a handsewn anastomotic technique. The reported leak rate varied significantly from 0% to approximately 30%. Rates of stenosis after handsewn anastomosis with RAMIE have not been reported, however, and are largely unknown.

Discussion

In 2020, Plat and colleagues published a systematic review that included 16 studies of robotic esophagectomy. They observed technical variation with increased use of robotic

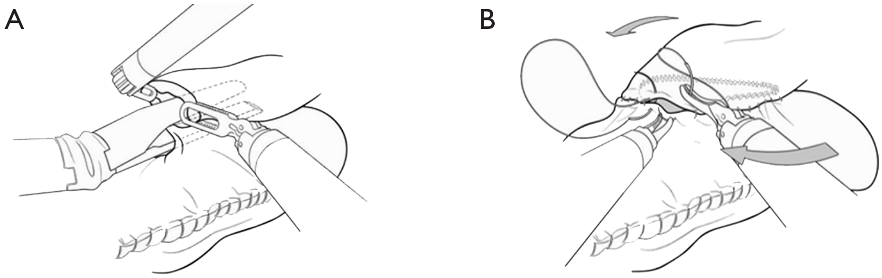

Figure 4 Linear stapling (A) with handsewn closure of the common defect (B). Reprinted with permission from Zhang *et al.* (13).

Table 3 Descriptive studies of the linear-stapled (hybrid) anastomotic technique with 10 or more patients

Authors	Year	Number	Technique	Size	Leak rate	Stricture rate	30-day mortality	90-day mortality
Hodari (21)	2015	54	Stapled, Sewn	45 mm	6%	NR	2%	NR
Zhang (13)	2019	35	–	~30 mm	8.6%	5.7% (post-op dysphagia)	0%	NR
Chouliaras (20)	2021	51	Stapled, Sewn	60 mm	3.9%	7.6%	0%	NR
Kandagatla (22)	2021	112	Stapled, Sewn	45 mm	8%	16.1%	0.9%	3.6%

NR, not reported; post-op, postoperative.

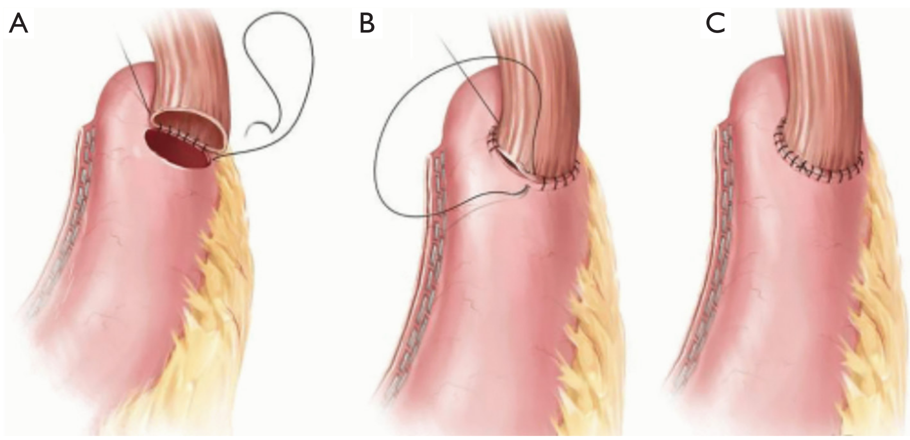

Figure 5 End-to-side handsewn anastomosis. From Oncohemakey.com/esophagectomy with permission.

Table 4 Descriptive studies of the handsewn anastomotic technique with 10 or more patients

Authors	Year	Number	Leak rate	Stricture rate	30-day mortality	90-day mortality
Cerfolio (23)	2013	16	0%	NR	0%	0%
Trugeda (24)	2014	14	29%	NR	0%	0%
Egberts (25)	2017	52	10%	NR	4%	NR
Zhang (12)	2018	26	8%	NR	0%	NR
de Groot (17)	2020	68	32% (25% > grade 1, 15% grade 3)	NR	NR	NR

NR, not reported.

surgery to perform esophagectomy and concluded that all thoracoscopic anastomotic techniques can be adopted using the robotic platform (6). Circular-stapled, linear-stapled (hybrid), and handsewn techniques have all been successfully employed to create the intrathoracic esophagogastric anastomosis necessary for RAMIE. Plat and colleagues observed greater initial adoption of circular-stapled anastomoses as the preferred technique, however, despite the need for an experienced assistant at bedside, and even though linear-stapled and handsewn techniques allow the surgeon complete control over the anastomosis from the console. The authors suggested that the circular-stapled anastomosis is the easiest to reproduce early in the learning curve, and somewhat simplified in comparison with standard MIE given the ability to sew the initial purse string with the robotic platform during RAMIE or the option to use the OrVil technique with introduction of the anvil transorally. Furthermore, the circular-stapled anastomosis may be the technique most familiar to surgeons who routinely perform non-robotic minimally invasive surgery or open esophagectomy.

Similarly, in an international cooperative group consensus statement by Li and colleagues, a 78% consensus was reported recommending mechanical stapling during RAMIE, although the authors acknowledged that the level of evidence supporting the recommendation is weak (1). The cooperative group further stated that after the surgeon accrues enough experience, the robotic platform likely augments performance of a handsewn anastomosis, a difficult task for many when using standard thoracoscopic techniques (1). An analysis of a multicenter, international RAMIE registry identified circular-stapled to be the most common method (52%) for anastomosis, followed by handsewn (30%) and linear-stapled (18%) (2).

I prefer the circular-stapled technique using a 28-mm EEA stapler to minimize the likelihood of stricture formation. I have found that this technique very reproducibly results in an end-to-end anastomosis that maximizes the margins of the resection. A handsewn, end-to-end anastomosis is my 2nd technique of choice. It similarly allows me to maximize the resection margins, and I appreciate that the anastomosis can be created entirely under the direct control of the console operator. I do not use the linear-stapled technique very often. I try to preserve as much stomach and esophagus as possible during RAMIE for resection of esophageal cancer to optimize the margins of the resection. This is more difficult with the linear stapler and might compromise the oncological efficacy of the procedure.

Early studies in patients undergoing open esophagectomy suggested no difference in outcomes with circular-stapled versus handsewn techniques, although potentially higher stricture rates may occur using the circular-stapled technique (26). Zhang and colleagues compared the results of their initial patient cohorts undergoing robotic esophagectomy with linear-stapled versus circular-stapled anastomoses and found the stricture rate was lower in patients with a linear-stapled anastomosis, but the difference was not statistically significant (13).

Although not focused on robotic approaches specifically, a meta-analysis of randomized controlled trials comparing circular-stapled and handsewn anastomoses identified a reduction in operative time when the circular-stapled technique was employed, but no difference in anastomotic leakage or mortality. They did also identify an increased risk of postoperative strictures after circular stapling, however (27). A similar meta-analysis reported like results, increased stricture rates with a circular-stapled anastomosis as compared with handsewn anastomoses and lowest rates of stricture in patients with a linear-stapled anastomosis, but also suggested increased risk of leak in patients with a handsewn anastomosis (28). A meta-analysis looking specifically at handsewn versus linear-stapled side-to-side techniques (both intrathoracic and cervical) corroborated a decreased leak rate overall using a linear-stapled anastomosis, as well as a decreased stricture rate. Importantly, for the purposes of this report, however, there were no differences in leak rates in patients with intrathoracic anastomoses (29). Interestingly, a large multicenter European registry trial comparing five anastomotic techniques used during transthoracic MIE identified higher rates of anastomotic leak with the "double-staple" OrVil technique (23%) versus the linear-stapled (16%) and the circular-stapled "purse-string" techniques (14%) (30). In an analysis of patients who underwent a robot-assisted Ivor Lewis esophagectomy, the highest leak rates were observed with handsewn anastomoses (33%) as compared with circular-stapled (17%) or linear-stapled (15%) (2).

In a detailed analysis of their adoption of a robotic, handsewn anastomotic technique after using a circular-stapled technique, de Groot and colleagues describe several technical refinements, made over time, including switching from an end-to-end anastomosis to an end-to-side anastomosis, switching brands of self-locking suture, and placing tension-release sutures (17). The authors identified a decrease in leak rates (using a moving average over 10 consecutive patients at a time) from 40% to 10%

Table 5 Potential comparative advantages and disadvantages of circular-stapled, linear-stapled, and handsewn anastomotic techniques

Anastomotic technique	Pros	Cons
Circular Stapled	Highly reproducible	Requires experienced user at bedside
	Different size options (25–31 mm)	Increased stricture rate *vs* hybrid?
	Quick	
OrVil Circular Stapled	Easier to deploy anvil	Limited size options (25 mm only)
		Higher stricture rate *vs* standard EEA?
		Requires experienced user at bedside
		Crossed staple lines
Handsewn	Fully robotic, console-surgeon controlled	Highly operator dependent (variability)
		Higher stricture rate? (end-to-end)
		Time consuming?
Linear Stapled	Fully robotic, console-surgeon controlled	Decreased margins?
	Simplest to execute, relatively quick	
	Decreased stricture rates?	

EEA, end-to-end anastomosis.

over the 68-patient experience, but acknowledged difficulty in determining what portion of the learning curve had been reached.

All the techniques described in this narrative review are acceptable for completing the intrathoracic anastomosis during RAMIE and, to date, none has been proven superior or been shown to result in fewer complications overall (*Table 5*). I advise surgeons adopting RAMIE to use the technique they are most comfortable with especially while they are learning. The surgeon should determine which approach he or she wants to use, observe an experienced robotic surgeon using that technique, and practice in a simulation or laboratory setting. Importantly, when they start performing RAMIE, I advise a low threshold early on for conversion to a technique they are experienced with and comfortable completing. The surgeon should convert to video-assisted thoracoscopic surgery (VATS) or even open surgery and should not feel compelled early in the learning curve to complete the anastomosis robotically if they have concerns. Studies of RAMIE adoption have suggested that proctoring and a modular step-up approach, with increasingly more of the esophagectomy procedure being completed using the surgical robot as the surgeon gains experience, may shorten the learning curve and ensure patient safety while the surgeon becomes accustomed to the new platform (31-33).

Conclusions

In conclusion, data regarding the "best" anastomotic technique for robotic assisted esophagectomy is very much in evolution. While linear-stapled anastomotic techniques appear to have the advantage of decreased stricture rates in most studies, similar overall rates of leak and anastomotic failure between the techniques have been suggested but not clearly delineated (*Table 5*). The circular-stapled method may be the most comfortable to adopt at the outset, while linear-stapled and handsewn techniques may grant the surgeon the ability to perform a complete robotic assisted anastomosis under direct control. Regardless of the technique chosen by any given surgeon, the most important factors likely remain surgical volume, surgeon experience, and technical comfort and facility with the chosen method.

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Footnote

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