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Editorial

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Evolution of transthoracic robotically-assisted minimally invasive esophagectomy (RAMIE) in the United States

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BACKGROUND

Esophageal cancer remains among the most lethal malignancies worldwide. In Western countries, its incidence has risen sharply in the past several decades, with the majority of cases diagnosed at an advanced stage. In 2025, an estimated 22,070 new cases of esophageal cancer are expected to be diagnosed in the United States, with approximately 16,250 related deaths[1].

The standard-of-care for early and locally advanced esophageal cancer of the lower two-thirds of the esophagus is neoadjuvant chemotherapy with or without radiotherapy, followed by esophagectomy. Esophagectomy remains one of the most challenging surgical procedures, historically associated with high morbidity and mortality rates.

The development of minimally invasive esophagectomy (MIE) in the early 1990s marked a significant milestone, demonstrating reductions in postoperative complications, blood loss, and length-of-stay compared with open surgery, while maintaining oncologic efficacy[2-4]. However, minimally invasive approaches are not without limitations. Challenges such as two-dimensional visualization, longer operative times, and limited instrument articulation can hinder surgical precision and ergonomics. Computer-assisted

or robotic surgery emerged as a solution to some of these problems.

THE TRANSTHORACIC APPROACH AND EARLY ROBOTIC INNOVATION

The transthoracic approach to esophagectomy, particularly the Ivor Lewis and McKeown procedures, became widely accepted over the 20th century as surgical techniques evolved following the first successful esophagectomy performed by Torek in 1913[5]. With the approval of robotic-assisted surgery by the U.S. Food and Drug Administration in 2000, pioneering surgeons sought to extend robotic technology to complex oncologic procedures, including esophagectomy.

FIRST ROBOTIC IVOR LEWIS AND MCKEOWN PROCEDURES

In 2002, Melvin and colleagues reported, without specific details, the first use of robotic assistance in an Ivor Lewis esophagectomy[6]. Unaware of this report and after searching with others for guidance, in November 2002, our team performed its first robotic-assisted chest-only laparoscopic-abdomen McKeown esophagectomy in our initial series[7]. We had seen the thoracoscopic aspect of esophagectomy procedures performed by Swanstrom and Luketich and realized that a robotic approach could offer significant advantages. However, optimizing the capabilities of the robot while ensuring a safe and efficient procedure required careful determination of the patient's position, port locations, and chassis placement[8]. Shortly thereafter, in 2003, Horgan and colleagues reported a robot-assisted transhiatal esophagectomy[7]. After an invited observation of Horgan's robotic abdominal approach, we adapted our technique to accommodate prior chest surgery and enable access to the left cervical region, and we reported the first completely robotic McKeown three-field esophagectomy in 2004[9]. This procedure achieved full robotic dissection and anastomosis, along with systematic cervical, mediastinal, and abdominal lymphadenectomy. In 2007, we reported our first series of completely robotic McKeown esophagectomies, which we later termed robotic-assisted lymphadenectomy esophagectomy (RALE), now referred to as robotic-assisted minimally invasive esophagectomy (RAMIE)[9].

These pioneering efforts laid the foundation for the broader adoption of robotic techniques in esophageal surgery, including the three-field esophagectomy. Over the subsequent decade, numerous centers worldwide refined and reported their experiences with robotic-assisted esophagectomy, demonstrating its feasibility and safety in high-volume institutions without the need for conversion or hybridization.

EVOLUTION AND IMPACT

Following these early pioneering efforts, numerous high-volume centers worldwide began adopting RAMIE and reporting their clinical experiences. Over time, both the technology and surgical techniques have advanced:

- Robotic systems have improved (e.g., da Vinci S, Si, and Xi platforms).
- Enhanced visualization and greater instrument articulation have enabled more precise dissection in anatomically challenging regions, such as the posterior mediastinum.
- Comparative studies have demonstrated reduced blood loss, improved lymph node harvest, and fewer pulmonary complications compared to open esophagectomy - and in some cases, even compared to conventional MIE.
- Randomized trials and multicenter studies, such as those from the Netherlands and South Korea, have further validated the safety, feasibility, and oncologic equivalence of RAMIE.

Importantly, our group's early experience with fully robotic procedures provided critical proof of concept: that complex, three-field esophageal resections could be performed safely using a completely robotic approach.

As robotic systems continue to evolve and become more accessible, their role in esophagectomy is expected to expand, potentially redefining the standard of care for esophageal cancer surgery. In parallel, efforts should be made to ensure equitable access to these technological advancements and to optimize patient selection criteria to fully harness the benefits of robotic surgery.

DECLARATIONS

Authors' contributions

Performed conceptualization, composition, and editing of this manuscript: Piyadeoglu D, Kernstine KH

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Both authors declared that there are no conflicts of interest.

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Consent for Publication

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