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Artificial Intelligence Surgery

Editorial

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The future implementation of artificial intelligence technology in esophageal surgery

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INTRODUCTION

The integration of robotics has significantly enhanced the ergonomics of minimally invasive esophagectomy (MIE), offering promising advantages in terms of safety and effectiveness[1]. The current mainstay of curative treatment is esophageal resection. The need to access the thoracic cavity has driven surgeons to perform esophagectomy in less invasive approaches in an attempt to reduce morbidity associated with thoracotomy. The robotic approach offers several potential benefits compared to traditional "open" and even minimally invasive laparoscopic approaches. These benefits may include improved visualization, enhanced dexterity, reduced blood loss, fewer incisions, and faster recovery times[2]. Studies have shown that, compared to non-robotic approaches, robotic THE has no apparent significant differences in charges, cost, or profitability[3]. One of the main hinderances to the widespread adoption of robotic technology in Surgery is its high cost. Therefore, improving the operative strategies and outcomes of esophageal resections is essential in mastering robotic THE.

Over the years, technical refinements in the procedure have led to enhanced short and long-term results. Robotic-assisted minimally invasive esophagectomy (RAMIE) was introduced as a solution to address the inherent limitations and technical challenges associated with traditional MIE. RAMIE has been proven to be a safe and viable alternative, resulting in reduced cardiopulmonary complications, wound infections, blood loss, and hospital stays compared to open esophagectomy. Recent meta-analyses and systematic reviews indicate that RAMIE is on par with conventional MIE, and the potential advantages mentioned above could soon lead to a shift in the standard care for resectable disease patients[4]. While numerous studies have examined open esophagectomy and MIE, a debate persists regarding the comparative oncologic effectiveness of the transhiatal (THE) and transthoracic (TTE) approaches. Comparative investigations between these two approaches suggest that the transhiatal approach offers an early survival advantage with lower mortality rates and higher 5-year survival rates, but no significant difference in long-term survival[5]. Moreover, several studies have noted that the THE approach may be the preferred method for older or high-risk surgical patients, as THE prioritizes minimizing complications and prompt postoperative recovery[6]. However, it is essential to note that despite advocating for this technique, its superiority over the transthoracic approach remains somewhat limited, as both methods have demonstrated satisfactory outcomes[7]. To this point, recent studies show that the volume of experience of the surgeon is probably a more important factor in predicting operative mortality and complication rates than the choice between the transthoracic approach and the transhiatal approach[8].

The FDA-approved da Vinci robotic platform by Intuitive Inc.® assists in a wide range of abdominal operations, particularly those involving deep and narrow anatomical spaces. The robot includes three fundamental techniques: freely swinging arms, three-dimensional high-definition video image technology, and human-computer interaction design of the main control console[9]. The performance of optical image instruments has promoted rapid development in machine vision technology. This enables surgeons to access challenging areas without the need for invasive maneuvers, providing excellent three-dimensional visualization and eliminating tremors. The robotic approach has not significantly changed the indications for esophagectomy, or the surgical techniques used. However, the use of the robotic platform can allow surgeons to perform MIE, which may curtail surgical insult to more patients.

In 2012, our institution performed its first robotic THE. Since then, we have transitioned our entire THE program from laparoscopic to RAMIE. This was done to increase the number of esophagectomy cases that are suitable for minimally invasive Surgery, thanks to the benefits of the Da Vinci platform. RAMIE has been demonstrated to be safe and effective in terms of oncological outcomes, but there is a learning curve, as with any new surgical technology. The learning curve for RAMIE necessitates improvements in operating time, blood loss, and lymph node yield. Studies have shown that RAMIE, compared to MIE, reduces the learning curve to 22 cases from a range of 35-119 cases. However, further results are needed to assess long-term results[10-13].

The transhiatal approach became popular as a less invasive alternative to the transthoracic method, primarily because it lowers the risk of complications and morbidity. By avoiding thoracotomy and intrathoracic anastomosis, this approach reduces the chance of pulmonary issues. Additionally, research from the Department of Surgery at Oregon Health and Science University has indicated that minimally invasive THE offers advantages such as improved lymph node retrieval compared to open THE and the ability to directly visualize the lower mediastinum without the need for blind resection. Instead of relying on tactile feedback for blunt dissection, the use of the robotic platform allows the surgeon to have a clear visual perspective on various anatomical structures during the procedure. This includes a lateral view of the pleural attachments, an anterior view of the heart, a posterior view of the aorta, and a comprehensive view of surrounding lymphoid tissues. In summary, while various approaches exist for conducting esophagectomy, the available literature indicates that the transhiatal approach is the most beneficial for early-stage cancer, benign diseases, and high-risk patients[14]. Robotic-assisted THE, in particular, offers enhanced visualization, reduced morbidity, and quicker recovery, while maintaining comparable oncologic outcomes.

ROBOTIC-ASSISTED MINIMALLY INVASIVE ESOPHAGECTOMY AND ARTIFICIAL INTELLIGENCE

Robotic Surgery enables surgeons to rapidly acquire proficiency in complex techniques, thereby reducing the learning curve[15]. At the first global AI gastroenterology and endoscopy summit in late 2019, multiple academic domains came together, concurring that, in the next ten years, the clinical applications of AI in gastroenterology will positively impact patient care and clinical workflow[16]. The field of Surgery is no exception. Indeed, the application of AI in the field of Surgery sets itself apart from AI in other medical domains due to the inherently interventional nature of Surgery. Providing a window of opportunity for robotic Surgery to pioneer groundbreaking advancements in healthcare.

AI- assisted robots are emerging as invaluable tools for surgeons. This technology combines the dexterity of human hands with the analytical power of AI algorithms, enabling them to perform complex surgical procedures with unparalleled accuracy and reliability. The collective body of evidence suggests that AI has the potential to enhance surgeons in multiple ways. Computer Vision (CV) is a field of study and technology that enables computers or machines to gain visual understanding from digital images or videos. Within computer vision, two particularly fascinating approaches to data analysis are motion analysis and time action analysis. In the pre-deep learning era, evaluating surgical skills required real-time observations of procedures or the review of recorded procedure videos. Gumbs *et al.* introduced a technique that focuses solely on data collected at non-continuous, predefined intervals. This approach allows for faster analysis and was noted to be particularly useful in assessing the placement of surgical clips[17]. Additional studies have shown that the application of machine learning technologies provides new methodologies to utilize large amounts of data for educational purposes[18].

It is important to keep in mind that surgeons are often evaluated on the basis of outcomes. These evaluations are generally conducted by surveys or videos and can be prone to bias[19]. Thus, objective assessment can be difficult to achieve. Measurements of technical proficiency extracted from AI algorithms have been shown to correlate with those given by expert surgeons. AI image processing has been shown to significantly improve the sensitivity, specificity, and accuracy of the images, suggesting the images displayed under the algorithm were of higher quality. This implies that we may be able to create a standardized grading system for surgical techniques, which may help further reduce the learning curve to RAMIE[20-23]. This will dramatically improve preoperative preparations and reduce postoperative complications for robotic THE. However, it is critical that these assessments are unbiased so that the true skill level of all surgeons is evaluated equally. Otherwise, the potential benefits of AI algorithms for surgical education and assessment could be undermined[24].

Furthermore, AI algorithms can act as decision-support tools during an operation, providing real-time analysis of data and offering recommendations to surgeons[25]. For novice surgeons, identifying crucial anatomical structures in the context of RAMIE remains a significant challenge. Although current platforms offer zoomed-in operating views, there is a need for additional assistance in orienting these views effectively. Previous research has primarily concentrated on less intricate procedures such as cholecystectomy due to their shorter learning curve. However, a study conducted at the University Medical Center (UMC) Utrecht focused on gathering surgical videos of RAMIE procedures, with particular attention to three key anatomical structures: the lungs, the vena cava/azygous vein, and the aorta. This study showcased the potential of a deep learning-based algorithm to segment these critical anatomical structures, which could aid in recognizing anatomy in the thoracoscopic RAMIE video frames[26]. Additionally, various research endeavors have suggested and implemented effective bottom-up strategies for forming annotator teams. Hashimoto *et al.* evaluated the efficacy and adaptability of their proposed team formation approach in the context of robot-assisted partial nephrectomy (RAPN) and RAMIE. Their findings underscored the critical role of surgical instrument detection in surgical AI projects while highlighting the absence of clear instructions for attaining high-quality data[27]. Through insights and predictive models, AI can help optimize surgical strategies, determine the best approach, and simulate the procedure to anticipate potential challenges.

In time, the incorporation of real-time feedback and haptic data into AI algorithms will enable robotic surgical systems to adapt to changing conditions, compensate for physiological motion, and enhance surgical precision[28]. Currently, one of the most notable instances of a self-operating tool is the Smart Tissue Autonomous Robot (STAR). This robot has successfully conducted *in vivo* robotic laparoscopic small bowel anastomosis. Its advanced autonomous approach permits the operator to choose from a variety of autonomously generated surgical plans, and the robot independently carries out a diverse range of tasks. Findings from the study's simulated model demonstrated that the autonomous system surpasses the manual techniques of expert surgeons and the RAS technique in terms of both consistency and precision[29]. If the ultimate aim is to enhance the independence of robots, perhaps research should shift its emphasis away from human-centric interpretations of haptics and instead concentrate on how robots and computers perceive haptics[29].

Surgeons are in a favorable position to facilitate the integration of AI into contemporary medicine. Leveraging AI in robotic Surgery, surgeons can use these prospective advancements to improve surgical outcomes, reduce complications, enhance patient safety, and expand their capabilities. However, the use of AI in Surgery is still evolving, and its implementation should always be supervised and guided by skilled healthcare professionals. We must encourage ongoing research and development efforts, support innovation, and invest in the training of healthcare professionals to fully unlock the transformative power of AI. When we embrace a mindset of continuous learning and improvement, we can propel the field of robotic Surgery forward and redefine the boundaries of what is possible in minimally invasive Surgery.

DECLARATIONS

Authors' contributions

Made substantial contributions to the conception and design of the study and performed data analysis, administrative, technical, and material support and interpretation: Peek G, Ross SB

Availability of data and materials

Not applicable.

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Conflict of interest

Dr. Sharona B. Ross is a consultant for Intuitive Surgical (Sunnyvale, CA) and Ethicon (Cincinnati, OH). Dr. Sharona B. Ross receives educational grants for her Women in Surgery Career Symposium from Intuitive Surgical and Medtronic (Minneapolis, MN).

Ethical approval and consent to participate

Not applicable.

Consent for publication
Not applicable.

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