Robotic surgery for esophageal cancer: what is the evidence?

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Esophageal cancer is a major public health burden, ranking 7th in terms of global cancer incidence and 6th in overall cancer mortality (1). Although esophageal squamous cell carcinoma (ESCC) is the most common histological type worldwide, Western countries have witnessed a rising incidence of esophageal adenocarcinoma (EAC) in the last decades (partly due to the increased prevalence of obesity) (2,3).

Multimodal therapies (i.e., chemotherapy, radiotherapy, immunotherapy, surgery) are often needed to treat esophageal cancer patients. Nevertheless, surgical resection remains the cornerstone in the management of early and locally-advanced esophageal cancer (4). An esophagectomy is a challenging and demanding operation, which requires refined surgical maneuvers and thorough anatomical knowledge of diverse surgical fields (i.e., abdomen, thorax and neck). Since its introduction in the early 1990s, minimally invasive esophagectomy (MIE) has been adopted by several centers achieving lower rates of postoperative complications and better quality of life, as compared to the conventional approach (5-7). MIE, however, is still technically complex (two-dimensional vision, straight non-articulated instruments, limited mediastinal surgical space, mirrored intracorporeal movements) and is associated with high morbidity rates (8).

Robotic surgery has well known advantages over open and conventional MIE (i.e., laparoscopy and thoracoscopy) that facilitate a more precise surgical dissection: enhanced visualization through high-definition and magnified three-dimensional (3D) imaging, stable surgical field, tremor filtration, fingertip control of EndoWrist instruments, and better ergonomics/reduced fatigue among others. The potential benefits of these technical advantages in esophageal cancer surgery have been explored in previous studies. A randomized trial comparing robot-assisted minimally invasive esophagectomy (RAMIE) with open transthoracic esophagectomy found that RAMIE had lower rates of overall surgery-related complications (59% *vs.* 80%, P=0.02), reduced pulmonary complications (32% *vs.* 58%, P=0.005), reduced cardiac complications (22% *vs.* 47%, P=0.006), lower postoperative pain, and better short-term quality of life. Oncological outcomes were comparable between both approaches (9). Another study also showed RAMIE was associated with decreased intraoperative blood loss, less pulmonary complications and reduced overall morbidity (10).

Opposite to the comparison between RAMIE and open esophagectomy, differences in outcomes between RAMIE and video-assisted esophagectomy are less notorious. Weksler *et al.* compared RAMIE with conventional MIE and found no significant differences in postoperative complications, length of intensive care unit stay or length of hospital stay, arguing that RAMIE did not offer clear advantages over thoracoscopic MIE (11). To note, only few patients were included in the analysis (11 *vs.* 26) and patients who had intrathoracic anastomosis were excluded. A larger propensity scored analysis compared RAMIE (n=66) with conventional thoracoscopic esophagectomy (n=66) and also reported similar outcomes in terms of blood loss, rates of overall complications, and length of stay (12). In line with these findings, a randomized trial including only patients with resectable ESCC showed that RAMIE and conventional MIE had comparable rates of overall complications, major complications, anastomotic leakage, and 90-day mortality. RAMIE, however, showed better thoracic lymph node dissection in patients who received neoadjuvant therapy as well as better lymph node dissection along the left recurrent laryngeal nerve (13). A recent meta-analysis including only patients with intrathoracic anastomosis did find benefits of RAMIE (n=974) over conventional MIE (n=5,275): less intraoperative blood loss, lower rates of postoperative pneumonia, reduced overall morbidity, and higher rates of R0 resections (14). Other studies also found superior left recurrent laryngeal lymph node dissection and lower incidence of recurrent laryngeal nerve paralysis with the robotic approach (15,16).

Medical expenditures related to the use of the robot are one of the Achilles' heel of robotic surgery. Both the acquisition and the periodic maintenance of a robotic unit represent an elevated economic burden. For that reason, many large academic institutions all over the world still do not have a robot (17). Cost-effectiveness analyses for robotic esophagectomy, however, are lacking. For instance, savings related to reduced postoperative complications and shorter length of hospital stay could counterbalance the higher costs of RAMIE, as compared to open esophagectomy. Better ergonomics associated with less work-related musculoskeletal complaints (common during conventional MIE) should also be considered (18,19). In addition, the development of new robotic platforms by other manufacturers will create competition in the market likely reducing the required expenses for robotic surgery.

Further advantages of robotic surgery might appear in the near future. Current platforms are capable of capturing kinematic data (e.g., instruments position, distance traveled, grip force) that could be used to design deep-learning models, evaluate surgical performance, and standardize procedures (20). Computerized platforms will also eventually allow navigational (i.e., image guided) surgery and artificial intelligence algorithms that could enhance esophageal cancer surgery.

Overall, current evidence shows that both RAMIE and conventional MIE are associated with better postoperative outcomes than open esophagectomy. In patients undergoing Ivor Lewis esophagectomy (i.e., intrathoracic anastomosis) the robotic approach might offer greater benefits than the classic thoracoscopic technique. In addition, lymph node dissection appears to be improved with the robotic platform. Potential oncological benefits associated with the use of robotic surgery, if any, remain elusive.

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