Review Article

Robotic-assisted Ivor-Lewis esophagectomy

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Abstract: Esophagectomy is the core treatment modality for operable esophageal cancer. For middle and lower third esophageal carcinoma, Ivor Lewis two stage esophagectomy is increasingly performed worldwide. In recent years, minimally invasive esophagectomy (MIE) has been widely applied, which has the superiority over open esophagectomy in terms of postoperative morbidity and mortality. The robotic surgical system provides a three-dimensional, high definition view, and improved stability and flexibility for operation, which unveiled a new era of MIE. Robot-assisted Ivor-Lewis esophagectomy (RAILE) has been suggested as a safe and feasible procedure for the treatment of operable middle and distal esophageal cancer. This review focuses on the perioperative and oncological outcomes of RAILE based on available evidence.

Keywords: Esophageal cancer; Ivor Lewis esophagectomy; robotic-assisted surgery

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Introduction

Esophageal cancer is one of the most common digestive tract cancers in the world (1). According to the Cancer Statistics in China, esophageal cancer ranks fourth in the incidence of malignant tumors (2). Most of the patients are in advanced stage at the time of diagnosis, and surgery is the cornerstone of the treatment for esophageal cancer (3). Open esophagectomy is usually accompanied by numerous complications and a high mortality rate (4,5). The presence of minimally invasive esophagectomy (MIE) significantly improved perioperative outcomes, without the compromise of long-term survival (6-8).

In the past two decades, robot-assisted thoracic surgery has been increasingly applied in clinical practice. Compared with video-assisted thoracoscopic surgery, robotic system provides a three-dimensional, higher definition view, and better dexterity in operation (9). The procedure of robot-assisted Ivor-Lewis Esophagectomy (RAILE) is a robotic esophageal cancer resection via right chest approach based on the technique of open and thoracoscopic Ivor-Lewis esophagectomy, which has the potential advantages in reducing postoperative complications (10) and performing intrathoracic hand-sewn anastomosis (11). The safety and technique feasibility of RAILE has been demonstrated by several studies (12-14). Here, we perform a literature review of published studies regarding the surgical outcomes of RAILE in different centers.

Surgical technique

Abdominal phase

RAILE begins with abdominal phase and patient is in the supine reverse Trendelenburg position. Four-arm approach is used in our center: a camera port is positioned in the subumbilical site, three robotic ports are placed in the right and left subcostal regions, with one assistant port placed on the left midclavicular line. After the gastric artery is transected, a complete celiac lymphadenectomy is

performed. Then the stomach is fully mobilized with the gastroepiploic arcade and the right gastroepiploic vessels preserved. The gastric conduit is then created by assistant with several fires of stapler. A jejunostomy is usually performed during abdominal phase for enteral nutrition support postoperatively in our department.

Thoracic phase

For the thoracic phase, the patient is positioned in the left lateral decubitus position, and one-lung ventilation is provided. Five ports are placed in the following position: a robotic camera trocar (12 mm) in the 5th intercostal space (ICS) on the anterior axillary line. The right robotic trocar (8 mm) was in the 8th ICS and the left robotic trocar (8 mm) was in the 3th ICS anterior to the scapular rim, an 8-mm port in the tenth ICS posteriorly to the posterior axillary line for the third robotic arm, and a 12-mm assistant's port in the 7th ICS near the costal margin. Thoracic phase usually begins with the lymph nodes dissection along right recurrent laryngeal nerve (RLN). The azygos vein is then divided by a stapler. The esophagus is then totally mobilized down to the gastroesophageal junction with dissection of all surrounding lymph nodes, including subcarinal areas, periaortic and periesophageal areas, as well as the lymph nodes along the left RLN. After the proximal esophagus is transected, intrathoracic anastomosis will be performed. For the digestive reconstruction, both stapled and hand-sewn intrathoracic anastomosis have been demonstrated as safe and technically feasible approaches (9).

Perioperative efficacy

Intraoperative parameters

The mean operation times of RAILE are variant among different institutions (12,15-19), range from 303 to 661 min. Generally, the average operation time of RAILE was significantly longer than thoracoscopic-assisted Ivor Lewis esophagectomy (TAILE). According to the reported of Nora *et al.* (20), the mean operation time of RAILE was 409 minutes, which was longer than thoracoscopic procedure (299 min, P=0.001). A comparative study in our center (17) also showed that the mean operation time of RAILE was significantly longer than TAILE (303 *vs.* 277 min, P=0.001).The reason for this mainly due to the additional installation time required for robotic surgery. Therefore, many centers performed laparoscopic combined with robotic surgery to shorten the operation time (13,21).

Meredith *et al.* (22) found that the blood loss in RAILE group was less than that in TAILE group (155±107 *vs.* 189±188 mL, P=0.03), by using a prospective database. However, according to the cases series in our center (17), no significant difference was found between RAILE and TAILE with respect to blood loss (200 *vs.* 200 mL, P=0.100).

The conversion rate of RAILE was relative low according to current literature (15,19,23), range from 0 to 4%. In a retrospective study including 61 cases in our center, only 1 case was converted to open (18).

Short term outcomes

In ROBOT trial, van der Sluis *et al.* (24) demonstrated that three stage robot-assisted minimally invasive esophagectomy (RAMIE) associated with better short-term outcomes in terms of intraoperative blood loss, postoperative complications, quality of life and postoperative pain compared to open esophagectomy. With numerous evidence supported three-stage RAMIE, it can be regarded as a good alternative to both open and thoracoscopic esophagectomy.

For the application of two stage RAMIE, several case series have demonstrated the surgical efficacy recently (20,21). de la Fuente *et al.* (21) reported an initial experience with 50 patients underwent RAILE: 14 patients (28%) had postoperative complications, including 5 (10%) with pneumonia and 1 (2%) with anastomotic leakage. In another retrospective study (20), which included 144 cases of RAILE, demonstrated that the incidence of postoperative complications was 23.6% (34 cases), with cardiac arrhythmias occurred most frequently (17.4%), and the incidence of anastomotic leakage was 2.8%. For the occurrence of anastomotic leakage, some studies suggested that it is related to anastomosis methods (25-29). Harustiak *et al.* (30) demonstrated that hand-sewn anastomosis appears to have a higher incidence of anastomotic leakage, compared to staple anastomosis (20.9% *vs.* 10.0%; P=0.002). Another retrospective study conducted in Japan also yielded similar results (31). However, a retrospective study conducted by Zhang *et al.* (18) in our department didn't find any difference of anastomotic leakage between two anastomosis approaches. The incidence of anastomotic leakage was 11.4% when using staple, while the rate of anastomotic leakage was 7.7% in hand-sewn group (P=0.960).

RLN is frequently and easily damaged when performing lymph nodes dissection, and causing paresis or palsy of the

vocal cords, which seriously damaging patients' quality of life (32). According to current studies, the incidence of RLN injury in MIILE, is 0 to 13.6% (7,33-35). Suda *et al.* (36) demonstrated the incidence of vocal cord paralysis (P=0.018) and hoarseness (P=0.015) can be reduced when using robot assistant, compared to control group. In our department, the incidence of vocal cord paralysis was 8.2% in a case series of RAILE (18).

According to the repot of Biere *et al.* (7), the median length of hospital stay was 11 days, and the mortality rate at 30 days was 2%. A propensity score-matched study (17) conducted by Zhang and colleagues showed that the length of hospital stay in the RAILE group was similar to TAILE group (9 *vs.* 9 d, P=0.517), and 30-day and in-hospital mortality is 0. What's more, a propensity-matched study conducted by Tagkalos *et al.* (14) demonstrated that ICU stay was shorter in the patient who underwent RAILE, compared to patient underwent TAILE (1 *vs.* 2 d, P=0.029).

Oncological outcomes

As a relatively new technology, data on the oncological outcomes of RAILE has always been the focus of attention. A lot of studies confirmed that a high lymph node yield significantly improve survival after esophagectomy (37-39). The ROBOT trial showed that the mean number of lymph nodes dissection was similar between three stage RAMIE and OTE (27 *vs.* 25, no significantly different) (24).

RAILE also can retrieve adequate lymph nodes according to previous studies, with a satisfactory radical resection (R0 resection) rate. A study (19) including 23 case of RAILE showed that RAMIE had a R0 resection rate of 96% (24/25), and the mean number of harvested lymph nodes was 26. Furthermore, Meredith *et al.* (22) demonstrated that RAILE can obtain better R0 resection rate and more harvest LN, compared to TAILE group (TAILE 93.5% *vs.* RAILE 100%, P=0.01; LN: TAILE 14±7 *vs.* RAILE 20±9, P<0.001).

The dissection of the paratracheal lymph nodes has a high therapeutic value for long-term survival, especially for patients with mid- to distal esophageal tumors (40). However, there are important structures nearby paratracheal lymph nodes, such as the superior vena cava and RLN. Severe bleeding and vocal cord paralysis will appear, when these structures were damaged (10). The advantages of robotic surgery might enable a meticulous and safe lymphadenectomy in paratracheal regions.

Horgan *et al.* (41) reported the completion of the world's first RAMIE in 2003. The development time of RAILE is even later, so few studies report the long-term survival data on patients. Weksler *et al.* (6) compared overall survival of patients underwent RAMIE, MIE, and OTE. No significant differences in survival were revealed, with a median survival of 48 months after RAMIE, 49 months after MIE, and 44 months after OTE (P=0.53).

Conclusions

Based on current evidence, RAILE is safe and technique feasible for the management of operable esophageal cancer. In terms of bleeding loss, rate of conversion, number of dissected lymph nodes, hospital stay, postoperative morbidity and mortality, RAILE has acceptable surgical outcomes. However, due to the short development of RAILE, long-term survival data is still lacking. What's more, high quality evidence is urgently needed to investigate whether RAILE can be considered as an alternative minimally invasive method for TAILE or open Ivor Lewis esophagectomy for the treatment of middle or distal esophageal cancer.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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