European Journal of Cardio-Thoracic Surgery 58 (2020) i65–i69
doi:10.1093/ejcts/ezaa212 Advance Access publication 2 July 2020

ORIGINAL ARTICLE

Cite this article as: Huang Y-H, Chen K-C, Lin S-H, Huang P-M, Yang P-W, Lee J-M. Robotic-assisted single-incision gastric mobilization for minimally invasive oesophagectomy for oesophageal cancer: preliminary results. Eur J Cardiothorac Surg 2020;58:i65–i69.

Robotic-assisted single-incision gastric mobilization for minimally invasive oesophagectomy for oesophageal cancer: preliminary results

Yu-Han Huang†, Ke-Cheng Chen†, Sian-Han Lin, Pei-Ming Huang, Pei-Wen Yang and Jang-Ming Lee *

Division of Thoracic Surgery, Department of Surgery, National Taiwan University Hospital and National Taiwan University College of Medicine, Taipei, Taiwan

* Corresponding author. Division of Thoracic Surgery, Department of Surgery, National Taiwan University Hospital and National Taiwan University College of Medicine, No. 7 Chung-Shan South Road, Taipei, Taiwan. Tel: 886-2-23123456 (ext 63940); fax: +886-2-23934358; e-mail: ntuhlee@yahoo.com (J.-M. Lee).

Received 28 January 2020; received in revised form 14 April 2020; accepted 17 April 2020

Key question

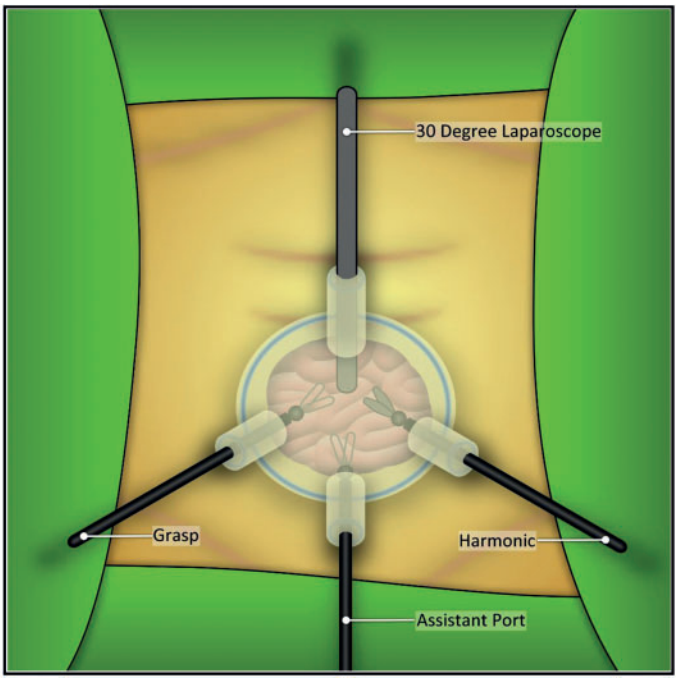
What is the role of robotic-assisted single-incision gastric mobilization for minimally invasive oesophagectomy in oesophageal cancer?

Key finding(s)

Eleven patients were included.
No deaths occurred; 1 case each of anastomotic leakage, pneumonia and hiatal hernia (9%).

Take-home message

Robotic single-incision gastric mobilization for minimally invasive oesophagectomy in treating oesophageal cancer is feasible.



Abstract

OBJECTIVES: With the gradual acceptance of robotic-assisted surgery to treat oesophageal cancer and the application of a single-port approach in several abdominal procedures, we adopted a single-port technique in robotic-assisted minimally invasive oesophagectomy during the abdominal phase for gastric mobilization and abdominal lymph node dissection.

METHODS: Robotic-assisted oesophagectomy and mediastinal lymph node dissection in the chest were followed by robotic-assisted gastric mobilization and conduit creation with abdominal lymph node dissection, which were performed via a periumbilicus single incision.

Presented at the 7th Asian Single Port VATS Symposium, Nagoya, Japan, 24–25 May 2019.
†The first two authors contributed equally to this work.

The oesophagogastrostomy was accomplished either in the chest (Ivor Lewis procedure) or neck (McKeown procedure) depending on the status of the proximal resection margin.

RESULTS: The procedure was successfully performed on 11 patients with oesophageal cancer from January 2017 to December 2018 in our institute. No surgical or in-hospital deaths occurred, though we had one case each of anastomotic leakage, pneumonia and hiatal hernia (9%).

CONCLUSIONS: Robotic single-incision gastric mobilization for minimally invasive oesophagectomy for treating oesophageal cancer seems feasible. Its value in terms of perioperative outcome and long-term survival results awaits future evaluation.

Keywords: Minimally invasive oesophagectomy • Single-port • Robotic-assisted gastric mobilization • Oesophageal cancer

ABBREVIATIONS

CT	Computed tomography
ICS	Intercostal space
MIE	Minimally invasive oesophagectomy

INTRODUCTION

The incidence of oesophageal cancer is increasing worldwide, especially in the White population [1, 2], thereby increasing the importance of technical issues in performing oesophagectomy, the mainstay treatment for the disease. Confronting the complexity and the substantial risk of surgical-related morbidity and mortality, minimally invasive oesophagectomy (MIE) that incorporates thoracoscopic and/or laparoscopic procedures has gradually emerged as a clinical practice that effectively helps reduce the risk of postoperative pain and pulmonary complications without compromising survival outcome [3–11]. However, the literature on this minimally invasive approach shows a continuous evolution, including the adoption of robotic systems and a single-port surgical approach [12–14]. Using robotic systems for the MIE procedure can help achieve a more precise dissection of the important deeply seated targets, such as the lymphadenectomy along the bilateral recurrent laryngeal region, with less risk of injury to the adjacent tissue [15]. We previously reported our results performing MIE with a single-incision approach using thoracoscopic and laparoscopic procedures, showing perioperative outcomes equivalent to those obtained without a multiple-incision approach [16, 17]. Encouraged by recent successful reports using robotic-assisted single-incision laparoscopic procedures in treating various hepatobiliary, pancreatic or obstetric and gynaecological diseases [18–20], we report our preliminary experience performing single-incision, robotic-assisted laparoscopic gastric mobilization for oesophageal reconstruction during MIE to treat oesophageal cancer.

PATIENTS AND METHODS

Patient selection

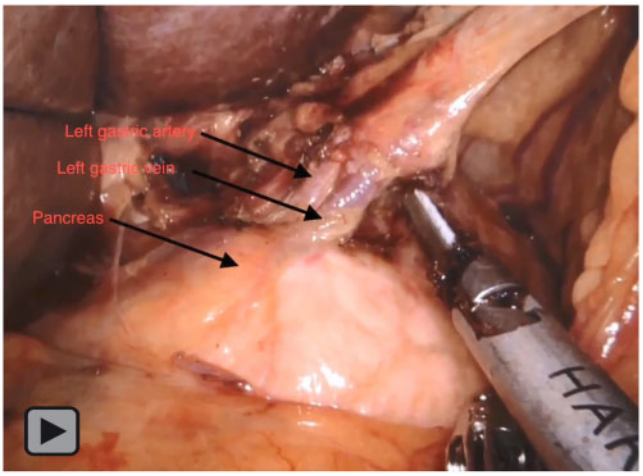
This study presents a retrospective analysis of patients with oesophageal cancer who had an oesophagectomy via robotic-assisted oesophagectomy and oesophageal reconstruction from January 2017 to December 2018 at the National Taiwan University Hospital, a 3200-bed tertiary medical centre. The oesophagectomy was performed via a four-arm robotic-assisted technique in the chest, whereas gastric mobilization in the abdominal phase was performed with a single-port robotic-assisted technique. The patient selection criteria included no previous operations in the chest or abdomen and the ability to tolerate one-lung ventilation and pneumoperitoneum during surgery. An oesophageal anastomosis with a gastric conduit was performed either in the neck (McKeown procedure) or chest (Ivor Lewis procedure) depending on the location of the tumour. All patients received computed tomography (CT), endoscopic ultrasound and positron emission tomography for staging studies. For patients with advanced disease (T3–T4 or N+), neoadjuvant concurrent chemoradiation therapy was followed by surgery 4–8 weeks later. The study was approved by the research ethics committee of the National Taiwan University Hospital (No: 201911091RINB).

Robotic-assisted oesophagectomy and mediastinal lymph node dissection

The patient was placed in a semi-prone position with the right upper extremity extended above the head. A four-port da Vinci robotic system (Intuitive Surgical Inc., Sunnyvale, CA, USA) was fitted with an 8-mm EndoWrist Grasper (Intuitive Surgical Inc.) for the left hand and an EndoWrist Scalpel (Intuitive Surgical Inc.) or Harmonic Scalpel (Ethicon Endo-Surgery, Inc., Cincinnati, OH, USA) for the right hand. These instruments were inserted, respectively, through the 9th or 10th intercostal space (ICS) in the posterior axillary line and in the 4th ICS in the midaxillary line, under an alternative use of 0° and 30° thoracoscopic cameras inserted through the 5th or 6th ICS in the posterior axillary line during the operation. A 2-cm assistant port was created over the 8th or 9th ICS in the posterior axillary line. Oesophageal mobilization was performed with lymph node dissection along the paraoesophageal and mediastinal lymph nodes including the bilateral recurrent laryngeal nerve and the pretracheal regions as proposed by the Japanese Society for Oesophageal Disease [21]. After oesophageal mobilization, the oesophagogastrostomy was performed either in the neck (McKeown oesophagectomy) or chest (Ivor Lewis oesophagectomy). As described below, the two procedures require different sequences for the abdominal phase of gastric mobilization, which is performed after the thoracic phase in the McKeown procedure and before it in the Ivor Lewis procedure. For the intrathoracic oesophagogastrostomy (Ivor Lewis), an OrVil transoral delivery system (DST PCEEA, 21 or 25 mm, Medtronic, Minneapolis, MN, USA) was used.

Robotic single-incision gastric mobilization

The gastric mobilization (Video 1) was performed with a Glove Port (Nelis Corp., Seongnam, Korea) inserted into a single 5-cm



Video 1: Single port robotic assisted gastric mobilization.

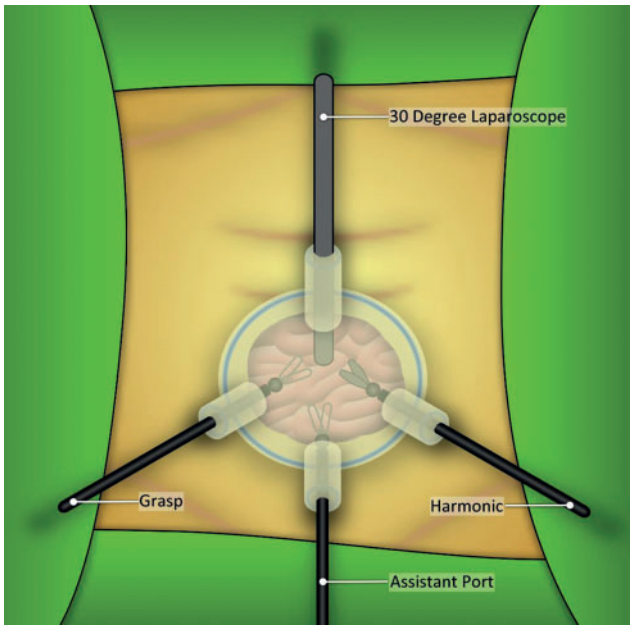


Figure 1: Placement of robotic instruments through the periumbilical single-incision wound. A 30°-downwards laparoscope was placed at the 12 o'clock position. The two robotic arms fitted with the EndoWrist Grasper and the Harmonic Scalpel were placed at the 8 and 4 o'clock positions, respectively; the assistant port was introduced at the 6 o'clock position.

incision near the umbilicus, which could be moved upwards for 1–3 fingerbreadths according to the patient's body height to allow the instrument to easily approach the diaphragmatic hiatus. A 30° downwards scope was placed at the 12 o'clock position, and the two robotic arms were fitted with an EndoWrist Grasper and a Harmonic Scalpel at the 4 and 8 o'clock positions, respectively (Fig. 1). The assistant port was introduced at the 6 o'clock position. By using the multiportal design of the Glove Port, the procedure only required one single-wound area around the umbilicus. The liver was elevated with a self-retaining stitch placed through the hiatus and fixed with an extracorporeal tie [16]. Dissection and mobilization of the stomach were performed with the EndoWrist Grasper and Harmonic Scalpel ultrasonic coagulating shears (Intuitive Surgical Inc.) along the greater and lesser curvature of the stomach, thus preserving the right gastric and gastroepiploic arteries. To facilitate movement of the robotic arms, the position of the robotic arm trocars was advanced somewhat when the procedures were performed near the hiatus. The lymph nodes along the left gastric and coeliac trifurcation were dissected during mobilization of the stomach. A gastric tube 5–7 cm in width was made by proximal gastrectomy with a linear stapler (EndoGIA 60 mm × 3.5 mm, Valleylab, Boulder, CO, USA or Ethicon Endosurgery, Cincinnati, OH, USA) using the single-port laparoscopic approach.

Table 1: Clinical characteristics of patients undergoing robotic-assisted single-incision gastric mobilization for minimally invasive oesophagectomy for oesophageal cancer

	Single-incision RAMIE ($n = 11$)
Gender, *n* (%)	
Male	10 (90.9)
Female	1 (9.1)
Age (years)	57.09
Cell type, *n*	
SQCC	9
ADC	1
Other	1
Tumour site, *n*	
Upper	2
Middle	5
Lower	1
Multiple	3
Neoadjuvant CCRT, *n*	
No	2
Yes	9
Tumour stage, *n*	
0	1
I	2
II	6
III	2
IV	0

ADC: adenocarcinoma; CCRT: concurrent chemoradiation therapy; RAMIE: single-incision robotic-assisted minimally invasive oesophagectomy; SQCC: squamous cell carcinoma.

Statistical analyses

The continuous clinical variables are presented as means and standard deviations. The statistical software package SPSS (SPSS Software, IBM Corp., Armonk, NY, USA) was used for analysis.

RESULTS

Table 1 displays the clinical characteristics of the 11 patients, including age, gender, tumour stage, concurrent chemoradiation therapy status and surgical treatment received. Table 2 shows the perioperative outcomes and surgical complications: leakage (one patient), pneumonia (one), cardiac arrhythmia (one), myocardial ischaemia (one), hiatal hernia (one) and vocal cord palsy (one).One patient incurred a left main bronchial laceration within the hemithorax during the oesophagectomy, which was repaired immediately during the operation without any sequelae. The patient with anastomotic leakage who had undergone a McKeown

Table 2: Perioperative outcomes of patients undergoing robotic-assisted single-incision gastric mobilization for minimally invasive oesophagectomy for oesophageal cancer

	Single-incision RAMIE (n = 11)
Lymph node dissection, *n*	
2 fields	1
3 fields	10
Surgical complications, *n*	
Left main bronchus laceration	1
Haemorrhagic shock	1
Hiatal hernia	1
Pneumothorax	1
Pneumonia	1
Leakage	1
LN dissected, number, mean ± SD	38.64 ± 14.35
Ventilator use (days), mean ± SD	1.91 ± 6.33
ICU stay (days)	6.55 ± 5.41
Hospital stay (days)	23.45 ± 17.37
Blood loss (ml)	598.18 ± 1014.54

ICU: intensive care unit; LN: lymph node; RAMIE: single-incision robotic-assisted minimally invasive oesophagectomy; SD: standard deviation.

oesophagectomy recovered after regular wet dressings were applied to the neck and was discharged 37 days after surgery. One patient had asymptomatic transient ST changes in the electrocardiogram and recovered after medication. One patient who underwent an Ivor Lewis oesophagectomy had a hiatal hernia noted on a CT follow-up scan 3 months after surgery, which was repaired laparoscopically. No surgical or hospital deaths occurred in our series. One patient was converted to open laparotomy due to bleeding near the left gastric artery during the MIE procedure.

DISCUSSION

MIE incorporating a robotic system has been gradually adopted in treating patients with oesophageal cancer because it offers an advantage over open surgery in lessening perioperative complications [22]. In addition, an oncological outcome equivalent to that with other surgical approaches can be achieved with robotic-assisted MIE [23]. Our preliminary experience demonstrates that a single-port robotic-assisted surgical technique can be effectively applied to the abdominal procedure in performing robotic-assisted gastric mobilization for oesophageal reconstruction.

Robotic-assisted single-site surgery with the da Vinci robotic single-site system has been used to perform cholecystectomy and various surgical procedures in obstetrics/gynaecology or prostectomy [18–20]. Instead of using the da Vinci robotic single-site system, robotic single-port procedures have been performed using a regular laparoscopic single-port device for distal pancreatectomy [24]. The results of the current study indicate that a similar technique can be effectively applied to gastric mobilization during robotic-assisted MIE. During the use of the regular da Vinci robotic surgical EndoWrist instruments and endoscope through a periumbilicus single-port device, the robotic endoscope was introduced at the 12 o'clock position with the scope turned upward 30°. The two robotic EndoWrist surgical arms were introduced at the 4 and 8 o'clock positions. The triangular space formed by the three robotic surgical arms provides adequate room for gastric mobilization and lymph node dissection. The assistant port was created at the 6 o'clock position with an elongated suction tube used for most of the procedure. When the procedures occurred near the gastric cardia, all surgical ports had to be moved slightly forwards to alleviate difficulty in surgical instrument manipulation due to the limited length of the robotic arm. In our series, one patient had a hiatal hernia that was discovered during post-surgical CT and repaired laparoscopically. Special care must be taken at the completion of the procedure near the hiatus where all the robotic arms and the scope have reached the limits of robotic manipulation. However, by adjusting the robotic trocars, the procedure can be performed with the robotic EndoWrist instrument under this setting without having to cross the two robotic arms. One patient in the initial period of our study underwent conversion to open laparotomy due to bleeding near the left gastric artery during the MIE procedure. The da Vinci robotic single-port system has previously been used to perform prostectomy [25]. Whether this new system can be effectively applied to the current procedure in the future after FDA approval needs further study.

Using a laparoscopic approach in MIE has been shown to help reduce surgical complications after oesophagectomy [26]. We also found that using a single-port procedure in MIE helped reduce wound pain following MIE [17]. Our preliminary experience shows the feasibility of adopting a single-port technique in robotic-assisted laparoscopic gastric mobilization. By adaptation of a triangular positioning of the robotic scope and the EndoWrists, a sufficient space for robotic manipulation can be maintained during the gastric mobilization procedure. However, this approach requires further evaluation to determine how well its immediate advantages translate into long-term clinical benefits for patients with oesophageal cancer. A recent European audit reported that the uniportal robotic approach for the abdominal step of the oesophagectomy is not being performed [27]. The situation was similar to ours in early days. We evolved gradually from laparotomy to multiportal laparoscopic gastric mobilization about 12 years ago, and, since 2012, we have adopted single-incision laparoscopy or multiportal robotic-assisted gastric mobilization. Following the accumulation of considerable experience with both approaches, this study presents single-incision robotic-assisted gastric mobilization. There are many ways to perform gastric mobilization for reconstruction after MIE. We think they are good methods as long as the surgeons feel confident about performing them. Although the audit in Europe found that the current operative method is not performed, it does provide an alternative approach that may benefit the patients. The audit could be expanded to a prospective randomized trial to compare different MIE techniques.

Moreover, the resection margins are of great importance. We evaluated the longitudinal margin by preoperative endoscopic clip localization. Regarding the circumferential margin, we performed meso-oesophagus *en bloc* resection for those cases, evaluating the circumferential margin by direct view with a three-dimensional magnificent view in the da Vinci system [28]. Postoperatively, we cut the resected specimen open and checked the localizing clip to confirm the longitudinal margin. If the margin was in doubt, we sent it for frozen section and cut additional margin as needed. At the end of the operation, we ensured that all margins were clear.

CONCLUSION

In conclusion, preliminary clinical results have demonstrated that a single-incision approach can be effectively applied to robotic-assisted gastric mobilization and abdominal lymph node dissection

in treating oesophageal cancer. Special care must be taken, especially during the procedure near the left gastric artery and when repairing the hiatus of the diaphragm after oesophagectomy, to lessen the risk of bleeding and hiatal hernia. Given the potential for incorporating robotic systems in minimally invasive surgery, future investigation of the clinical value of single and reduced-port techniques in performing robotic-assisted surgery for oesophagectomy and oesophageal reconstruction is warranted.

Funding

This study was supported by the Ministry of Science and Technology (MOST 108-2314-B-002-017 and MOST 107-2314-B-002-248-MY3), National Taiwan University Hospital (NTUH.109-S4638), the Center of Excellence for Cancer Research (2018–2021), National Taiwan University Hospital (MOHW108-TDU-B-211-124017), Taiwan Health Foundation, and Taiwan Society for the chest care of the Republic of China.

Conflict of interest: none declared.

Author contributions

Yu-Han Huang: Investigation; Resources; Writing—original draft; Writing—review & Editing. **Ke-Cheng Chen:** Investigation; Data curation; Resources; Writing—review & editing. **Sian-Han Lin:** Software. **Pei-Ming Huang:** Investigation; Resources. **Pei-Wen Yang:** Data curation. **Jang-Ming Lee:** Conceptualization; Data curation; Investigation; Writing—original draft; Writing—review & editing.

Reviewer information

European Journal of Cardio-Thoracic Surgery thanks Luca Luzzi, Marcello Migliore and the other, anonymous reviewer(s) for their contribution to the peer review process of this article.

REFERENCES

[1] Allum WH, Stenning SP, Bancewicz J, Clark PI, Langley RE. Long-term results of a randomized trial of surgery with or without preoperative chemotherapy in esophageal cancer. J Clin Oncol 2009;27:5062–7.
[2] Enzinger PC, Mayer RJ. Esophageal cancer. N Engl J Med 2003;349: 2241–52.
[3] Luketich JD, Alvelo-Rivera M, Buenaventura PO, Christie NA, McCaughan JS, Litle VR *et al*. Minimally invasive esophagectomy: outcomes in 222 patients. Ann Surg 2003;238:486–94. discussion 494–5.
[4] Smithers BM, Gotley DC, Martin I, Thomas JM. Comparison of the outcomes between open and minimally invasive esophagectomy. Ann Surg 2007;245:232–40.
[5] Palanivelu C, Prakash A, Senthilkumar R, Senthilnathan P, Parthasarathi R, Rajan PS *et al*. Minimally invasive esophagectomy: thoracoscopic mobilization of the esophagus and mediastinal lymphadenectomy in prone position–experience of 130 patients. J Am Coll Surg 2006;203:7–16.
[6] Sutton CD, White SA, Marshall LJ, Berry DP, Veitch PS. Endoscopic-assisted intrathoracic oesophagogastrostomy without thoracotomy for tumours of the lower oesophagus and cardia. Eur J Surg Oncol 2002;28: 46–8.
[7] Senkowski CK, Adams MT, Beck AN, Brower ST. Minimally invasive esophagectomy: early experience and outcomes. Am Surg 2006;72: 677–83. discussion 683.
[8] Nguyen NT, Roberts P, Follette DM, Rivers R, Wolfe BM. Thoracoscopic and laparoscopic esophagectomy for benign and malignant disease: lessons learned from 46 consecutive procedures. J Am Coll Surg 2003;197: 902–13.
[9] Nguyen NT, Schauer P, Luketich JD. Minimally invasive esophagectomy for Barrett's esophagus with high-grade dysplasia. Surgery 2000;127: 284–90.
[10] Martin DJ, Bessell JR, Chew A, Watson DI. Thoracoscopic and laparoscopic esophagectomy: initial experience and outcomes. Surg Endosc 2005;19:1597–601.
[11] Leibman S, Smithers BM, Gotley DC, Martin I, Thomas J. Minimally invasive esophagectomy: short- and long-term outcomes. Surg Endosc 2006; 20:428–33.
[12] Li NL, Peng WL, Liu CC, Shih CH. Comparison of the short-term postoperative results of prone positioning and lateral decubitus positioning during thoracoscopic esophagectomy. Wideochir Inne Tech Maloinwazyjne 2015;1:37–43.
[13] Kawasaki K, Oshikiri T, Kanaji S, Nakayama S, Kominami H, Tanaka K *et al*. Thoracoscopic esophagectomy in prone position: advantages of five ports over four ports. Hepatogastroenterology 2015;62:69–72.
[14] Zhang J, Wang R, Liu S, Luketich JD, Chen S, Chen H *et al*. Refinement of minimally invasive esophagectomy techniques after 15 years of experience. J Gastrointest Surg 2012;16:1768–74.
[15] Park SY, Kim DJ, Kang DR, Haam SJ. Learning curve for robotic esophagectomy and dissection of bilateral recurrent laryngeal nerve nodes for esophageal cancer. Dis Esophagus 2017;30:1–9.
[16] Lee JM, Yang SM, Yang PW, Huang PM. Single-incision laparothoracoscopic minimally invasive oesophagectomy to treat oesophageal cancer. Eur J Cardiothorac Surg 2016;49:i59–63.
[17] Lee JM, Chen SC, Yang SM, Tseng YF, Yang PW, Huang PM. Comparison of single- and multi-incision minimally invasive esophagectomy (MIE) for treating esophageal cancer: a propensity-matched study. Surg Endosc 2017;31:2925–31.
[18] Grochola LF, Soll C, Zehnder A, Wyss R, Herzog P, Breitenstein S. Robot-assisted versus laparoscopic single-incision cholecystectomy: results of a randomized controlled trial. Surg Endosc 2019;33:1482–90.
[19] Matanes E, Lauterbach R, Boulus S, Amit A, Lowenstein L. Robotic laparoendoscopic single-site surgery in gynecology: a systematic review. Eur J Obstet Gynecol Reprod Biol 2018;231:1–7.
[20] Han HJ, Kang CM. Reduced port minimally invasive distal pancreatectomy: single-port laparoscopic versus robotic single-site plus one-port distal pancreatectomy. Surg Endosc 2019;33:1091–9.
[21] Japanese Committee for Registration of Esophageal Carcinoma. A proposal for a new TNM classification of esophageal carcinoma. Jpn J Clin Oncol 1985;15:625–36.
[22] van der Sluis PC, van der Horst S, May AM, Schippers C, Brosens LAA, Joore HCA *et al*. Robot-assisted minimally invasive thoracolaparoscopic esophagectomy versus open transthoracic esophagectomy for resectable esophageal cancer: a randomized controlled trial. Ann Surg 2019;269: 621–30.
[23] Espinoza-Mercado F, Imai TA, Borgella JD, Sarkissian A, Sema-Gallegos D, Alban RF *et al*. Does the approach matter? Comparing survival in robotic, minimally invasive, and open esophagectomies. Ann Thorac Surg 2019;107:378–85.
[24] Peng CM, Liu HC, Hsieh CL, Yang YK, Cheng TC, Chou RH *et al*. Application of a commercial single-port device for robotic single-incision distal pancreatectomy: initial experience. Surg Today 2018;48: 680–6.
[25] Agarwal DK, Sharma V, Toussi A, Viers BR, Tollefson MK, Gettman MT *et al*. Initial Experience with da Vinci Single-port Robot-assisted Radical Prostatectomies. Eur Urol 2019;19:30280–5.
[26] Mariette C, Markar SR, Dabakuyo-Yonli TS, Meunier B, Pezet D, Collet D *et al*. Hybrid minimally invasive esophagectomy for esophageal cancer. N Engl J Med 2019;380:152–62.
[27] Oesophago-Gastric Anastomosis Study Group on behalf of the West Midlands Research Collaborative. International variation in surgical practices in units performing oesophagectomy for oesophageal cancer: a unit survey from the oesophago-gastric anastomosis audit (OGAA). World J Surg 2019;43:2874–84.
[28] Migliore M, Rassl D, Criscione A. Longitudinal and circumferential resection margin in adenocarcinoma of distal esophagus and cardia. Future Oncol 2014;10:891–901.