

Total (Transthoracic and Transabdominal) Robotic Radical Three-Stage Esophagectomy—Initial Indian Experience

S. P. Somashekhar¹ · Rajshekhar C. Jaka¹

Received: 7 September 2015 / Accepted: 28 April 2016 / Published online: 14 May 2016
© Association of Surgeons of India 2016

Abstract This study aims to evaluate the safety and technical feasibility of total robot-assisted three-stage esophagectomy. From July 2011 to June 2014, 35 histologically proven resectable carcinoma esophagus patients underwent robot-assisted transthoracic and transperitoneal three-stage esophagectomy. In the initial ten cases, total docking time, thoracic docking time, total operative time, thoracic-phase operative time, and blood loss were 67.9 ± 13.24 , 32.2 ± 9.74 , 429.2 ± 57.65 , and 96.6 ± 20.33 min and 433.20 ± 48.72 ml, respectively. In the subsequent 25 cases, all parameters decreased significantly (33.20 ± 4.16 , 13.76 ± 3.43 , 321.13 ± 13.75 , and 57.04 ± 9.15 min and 256.32 ± 17.52 ml, respectively). Median numbers of lymph node dissected were 32. One case was converted to open method, and there was no in-hospital or 30-day mortality. Two cases required ventilator support for 1 day, with ICU stay for 1 day in 15 patients and 2 days in five patients. Two patients had major complications. Median hospital stay was 8 days. All had microscopic negative resection margins. Robot-assisted three-stage esophagectomy has the benefits of minimally invasive surgery and immediate oncological outcomes are comparable to conventional open surgery. Therefore, it is a safe and feasible technique for the treatment of esophageal cancer in selected patients.

Keywords Robotic transthoracic esophagectomy · Minimally invasive esophagectomy · Three-stage esophagectomy · Total robotic esophagectomy

✉ Rajshekhar C. Jaka
rajjaka@yahoo.com

¹ Manipal Comprehensive Cancer Center, Manipal Hospital, HAL Airport Road, Bangalore, Karnataka, India 560017

Introduction

Esophageal cancer is the eighth most common cancer and sixth leading cause of cancer deaths in the world, with the majority of cases occurring in developing countries [1]. Radical surgical resection of the esophagus and surrounding lymph nodes offers the best chance for cure in patients with locoregional disease [2]. Transhiatal esophagectomy carries a lower complication rate but only a limited lymphadenectomy can be carried out [3]. Transthoracic esophagectomy allows en bloc resection of the esophagus and extensive mediastinal lymphadenectomy, but is associated with significant morbidity [3]. To reduce surgical trauma and the morbidity of esophagectomy, minimally invasive techniques have been developed.

Conventional thoracoscopic esophagectomy has many limitations. Robotic systems have been designed to overcome some of the disadvantages of standard minimally invasive surgery. Robotic systems facilitate precise dissection in a confined thoracic cage. The Da Vinci robotic system (Intuitive, Sunnyvale, CA, USA) provides a three-dimensional, tenfold magnified view of the operating field, filtering the tremor of the surgeon's hand and endowrist instrumentation technology mimicking the human hand which offers 7° of movement versus the limited 4° of movement in laparoscopy [4]. In the present study, we evaluated the feasibility and technique of robot-assisted thoracic and abdominal phase of three-stage esophagectomy and lymphadenectomy in patients with esophageal carcinoma.

Materials and Methods

A prospective observational study was undertaken from July 2011 to June 2014 at our institute. Forty-one consecutive

histologically proven (T1–4a, N+, M0) carcinoma esophagus patients with ECOG performance status of 0 and 1 were included in the study. Patients with locally advanced lesion ($\geq T3$, N1) on imaging (EUS, CECT/PET-CT), underwent neoadjuvant chemotherapy (paclitaxel, cisplatin, 5-fluorouracil). Patients who progressed or have unresponsive T4a lesions with neoadjuvant chemotherapy, with multistation bulky lymphadenopathy, a lesion in cervical esophagus or less than 5 cm from cricopharyngeus, with distant metastasis, and patients unfit for general anesthesia were excluded from the study. Surgically resectable patients underwent robot-assisted transthoracic and transperitoneal three-stage esophagectomy (Figs. 1 and 2). Technique and feasibility of robot-assisted surgery in terms of operating time, estimated blood loss, total number of lymph nodes retrieved, postoperative ventilator support, ICU stay, hospital stay, conversion to open procedure, margin status (mucosal and circumferential), intraoperative and postoperative complications were analyzed. Complications were classified according to modified Clavien–Dindo classification (MCDC) of surgical complications [5]. Ethical board approval was taken for the study. Informed consent was taken from all the patients included in the study. Descriptive and inferential statistical analyses were done.

Results

A total of 35 patients (including 21 patients after neoadjuvant therapy) were selected for robot-assisted surgery and included in the study for evaluation (Tables 1, 2, and 3). Initially, we took 45 (32.20 ± 9.74) min to dock in thoracic phase but after ten cases, it came down significantly to 18 min (range 45–18 min). In subsequent 25 cases, thoracic docking time ranged

from 18 to 10 min. The decrease in the time for thoracic-phase docking was significantly less in the subsequent group (p value < 0.001). As we became more familiar with the anatomy and maneuverability of instruments, the time taken to dissect the esophagus with regional lymphadenectomy decreased significantly. The most important obstacle was a prominent spine in our set of patients, restricting arm movements. We could overcome this by modification of port placements according to the varied anatomy of the patient and the use of an umbilical tape around the esophagus to facilitate the dissection. Thoracic-phase operative time was 140 min in the beginning which came down significantly after the initial ten cases, ranging from 140 to 74 min (mean \pm SD = 57.04 ± 9.15). One patient had a bulky tumor and in an effort for R0 resection, the thoracic duct opened up just below the level of the carina and was detected intraoperatively. While ligating the thoracic duct at the lower end of the thoracic cage, an azygous vein was injured and immediate conversion thoracotomy was done to control the bleeding. This was the only intraoperative complication we had in our series.

Total docking time (thoracic phase and abdominal phase) was 90 min when we started the study, and after ten cases, it was 50 min. In the subsequent 25 cases, it ranged from 40 to 25 min. The mean decrease in total docking time after the initial ten cases was significant ($p < 0.001$). The total operative time from thoracic incision to closure of cervical and abdominal wounds was 500 min in the beginning and significantly decreased in subsequent 25 cases and has reached 300 min in the last few cases.

Total blood loss in the entire surgery came down from 500 to 300 ml after the initial ten cases. In the subsequent cases, it was ranging from 300 to 240 ml. Mean blood loss was 433.20 ± 48.72 ml in the initial ten cases and 256.32 ± 17.52 ml in the subsequent 25 cases. The decrease was significant. Median

Fig. 1 Port placement for thoracic phase of esophageal mobilization (prone position) R1—arm one, C—camera, R2—arm two, A—assistant

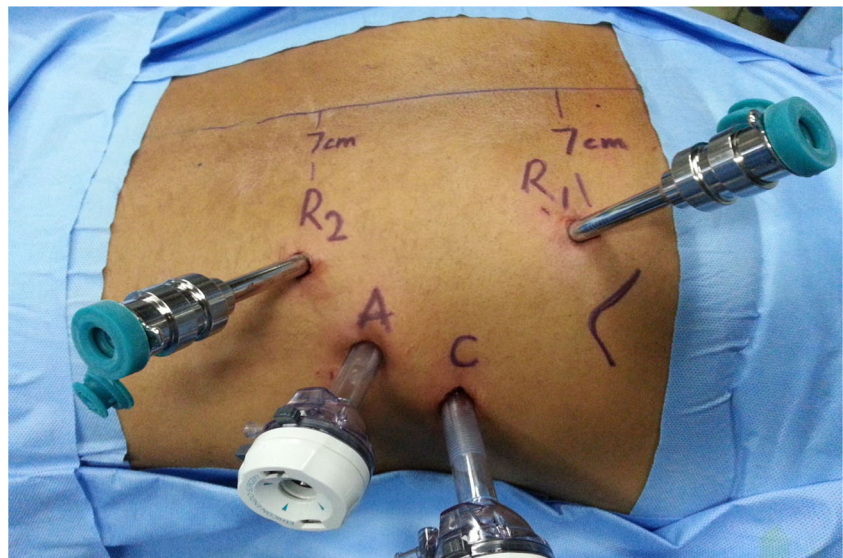
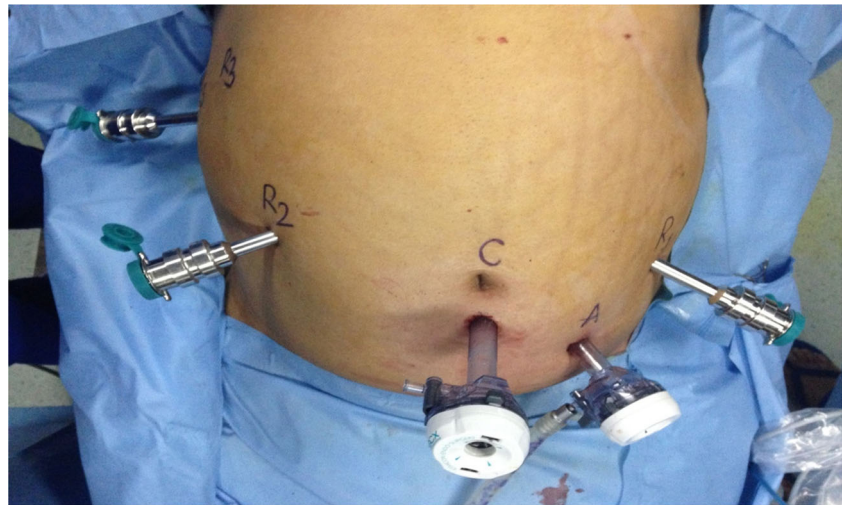


Fig. 2 Abdominal-phase port placement (leg end view). *R1*—first arm, *A*—assistant, *C*—camera, *R2*—second arm, *R3*—third arm



number of lymph nodes removed was 32 (range 12–48). All 35 cases had R0 resection on final histopathology report. Two patients could not be extubated during the immediate postoperative period and were on ventilator support for 24 h. Fifteen cases were in ICU care for 1 day and five cases for 2 days. Ten cases never required intensive care. There was no in-hospital or within 30 days mortality in our series. There were no complications like anastomotic leak, gastric tube necrosis, chylous leak, and permanent vocal cord paralysis. One patient had temporary vocal cord palsy which recovered its function by the end of 3 weeks. All patients were fed through feeding jejunostomy from the second postoperative day. One patient had delayed gastric emptying in spite of pyloroplasty and underwent one-time endoscopic balloon dilatation with prokinetic treatment for 1 week. On the seventh postoperative day, one patient was diagnosed with diaphragmatic hiatus hernia. In this patient, a part of the diaphragm was resected during surgery as tumor was at the GE junction and close to the diaphragm. The transverse colon and small bowel loops were herniated into the left side of the thorax by the side of the gastric tube. He underwent laparoscopic reduction of hernia with suturing of the diaphragm to reduce the enlarged hiatus

opening. The median hospital stay was 8 days (range 6–13) in our series.

Discussion

Robotic systems have been designed to overcome some of the disadvantages of standard minimally invasive surgery with a short learning curve and ease of lymphadenectomy. The prone position was used because it is known to facilitate mediastinal dissection and minimize lung injury [6]. Lung injury is minimized as lung retraction is not necessary because it falls down by gravity, bleeding does not obscure the operative field, and exposure of the infra-aortic area and tracheobronchial tree is excellent. It also allows controlled right lung ventilation. We never had any problem operating in this position. Noshiro et al. [7] and Fabian et al. [8] in their comparison of prone versus left lateral decubitus position during thoracoscopic esophageal mobilization found many advantages with prone position. In thoracic-phase port placement, Boone et al. [9] and van der Sluis et al. [10] have reported the use of two assistant ports in the left lateral decubitus position. We used one assistant port with ease in the prone position, as is reported by Kim et al. [11].

Abdominal-phase robot-assisted surgery is rarely reported in the literature. In our series, the abdominal part was done with robotic assistance. Placing the arm-two port 4 cm above the midpoint of a line-joining camera port and arm-three port is important in dissection along the greater curvature and lesser curvature of the stomach and along the celiac axis and left gastric artery with the help of a harmonic scalpel. Retraction of the liver was done with the prograsper in arm three, without the need for a special dedicated liver retractor.

Two articles about conventional minimally invasive esophagectomy show that minimally invasive esophagectomy in general is superior over open esophagectomy [12, 13].

Table 1 Clinical data profile

Age (years)	Range 38–72 Median 61
Sex distribution	Male—20 Female—15
Location of tumor	Upper thoracic—3 Mid thoracic—18 Lower thoracic and GE junction—14
Histology	Squamous cell—26 Adenocarcinoma—9
Staging	T2N0 = 14 T2N+, T3N0, T3N+ = 21
Neoadjuvant therapy	Chemotherapy—21

Table 2 Operative data profile

Variables	Initial ten cases (Mean ± SD)	Subsequent 25 cases (Mean ± SD)	<i>p</i> value
Total docking time (min) (thoracic and abdominal phase)	67.90 ± 13.24	33.20 ± 4.16	<0.001
Thoracic-phase docking time (min)	32.20 ± 9.74	13.76 ± 3.43	<0.001
Total operative time (thoracic, abdominal, and cervical phase)	429.20 ± 57.65	321.13 ± 13.75	<0.001
Thoracic-phase operative time (min)	96.60 ± 20.33	57.04 ± 9.15	<0.001
Total blood loss (ml)	433.20 ± 48.72	256.32 ± 17.52	<0.001

Thoracoscopic esophagectomy necessitates a substantial amount of learning, even for experienced thoracoscopic surgeons [14]. Robot-assisted surgery has the potential to accelerate the learning curve of minimally invasive esophagectomy (MIE) because it has several advantages, including increased magnification with three-dimensional view, articulation of instruments, improved dexterity, and better ergonomics [15]. Kim et al. [11] reported a significant decrease in console time after six cases, and this led to a decrease in total operation time with a resultant high percentage of immediate postoperative extubation. We achieved significant reduction in docking time and operative time after initial ten cases. After initial ten cases, there was no significant improvement observed in the learning curve for the subsequent group of 25 patients and we nearly reached a plateau. The selection of ten cases in the initial group was based on this observation and our previous experience with robotic surgery for endometrial cancer [16].

Kim et al. [11] reported a significant decrease in thoracic docking time to 14.8 ± 10.6 min after initial six cases. We took 13.76 ± 3.43 min, after initial ten cases. They reported a significant decrease in thoracic-phase operative time to 81.7 ± 16.5 min after the initial six cases, and in our series, it was 57.04 ± 9.15 min after initial ten cases. Osugi and colleagues [14]

reported in their series of 80 thoracoscopic esophagectomies that a plateau in technique was not reached until 34 cases had been performed. It indicates that robotic technique has a shorter learning curve. Total operative time was longer in our initial ten cases (429 ± 57.65 min), but came down to 321.13 ± 13.75 in subsequent cases. As the experience of a surgeon in robotic surgery increases, the time taken for total surgery is expected to come down further. It is comparable to the median time taken for transthoracic open esophagectomy (360 min) [3].

In a surgical treatment of esophageal cancer, greater extent of lymphadenectomy is reported to be associated with increased survival [17]. Boone et al. [9] dissected a median of 29 lymph nodes with robotic esophagectomy, which is comparable to the 31 lymph nodes reported for two-field lymph node dissection in open transthoracic esophagectomy [3]. Their study has shown that robotic transthoracic esophagectomy offers a lymphadenectomy and radical resection rate similar to that of open transthoracic surgery. Even in our study, the median number of lymph nodes retrieved was 32 and is comparable to other studies. The extensive upper mediastinal lymph node dissection provided by robot-assisted esophagectomy would not have been dissected by a transhiatal approach [3]. Median number of lymph nodes retrieved was significantly higher with MIE versus open esophagectomy (16 versus 10) attributed to better visualization with MIE [18].

Boone et al. [9] reported median blood loss during the robotic thoracoscopic phase was 250 (range 0–800) ml and for the entire procedure was 625 (range 150–5300) ml. They reported significant decrease in total blood loss between the first 23 and second 24 patients (median 900 versus 450 ml, respectively; *p* < 0.001). Overall blood loss of the robotic method seems less than for the open method [19]. In our series, we had significant decrease in blood loss after initial ten cases and was less than 300 ml in the last 15 cases.

The completeness of tumor resection rate was comparable to the open transthoracic surgery. With regard to tumor infiltration of the resection margins, the R0 resection rate in the Boone et al. [9] series of robotic transthoracic esophagectomy was 77 %, which is similar to that of open transthoracic series [3]. In our series, all the cases had R0 resection (100 %). Robotic surgery is a replication of steps done in an open

Table 3 Operative and postoperative data profile

Number of lymph nodes retrieved	Median—32 Range—13 to 48
Conversion to open	1 (azygous vein bleeding)
In hospital or 30 days mortality	0
Complications	Major: Pneumonitis—1 Diaphragmatic hiatus herniation—1 Minor: Wound infection—0 Pleural effusion—0 Delayed gastric emptying—1 Temporary vocal cord palsy—1 R0 resection—35
Margin status (proximal, distal, circumferential)	
Postoperative ventilator support	2 patients for 1 day
ICU stay	15 patients—1 day 5 patients—2 days
Hospital stay (days)	Median 8 Range 6–13

surgery, with advanced technological support. As routine, we take either-side pleural margin and do cervical anastomosis, and because of our selective inclusion criteria to operate, our R0 resection rates are high in open as well as robotic surgery. However, a large study is required to confirm our early results.

In a systematic review by Decker and colleagues [20], centers reporting fewer than 25 cases of MIE had a 3.9 % mortality rate, 30.8 % respiratory complication rate, and 9.6 % conversion rate. In our series, we had no mortality, 2.85 % pulmonary complication rate, and 2.85 % conversion rate. Under hydration during surgery, minimal handling of the lung during surgery in the prone position, both lung ventilation during surgery, serial intraoperative intercostal nerve block, immediate on-table postoperative extubation, short-duration ICU stay, and comfortable breathing postoperatively because there is no pain associated with thoracotomy will explain the low pulmonary complications in our series. In the open transthoracic esophagectomy, high pulmonary complications (57 %) were reported [3]. Because of the endowrist technology with magnified view in the robot-assisted surgery, we could complete most of the surgeries robotically with a low conversion rate. In an open-label, randomized trial of 115 patients, those undergoing an open transthoracic esophagectomy had a significantly higher rate of pulmonary complications compared with patients undergoing a minimally invasive esophagectomy (29 versus 9 %) [12]. Median ventilation time for open transthoracic esophagectomy reported was 2 days (0–79) [3]. In our series, only 2 patients required support of ventilator for 1 day (mean 0.062), which is significantly less. Median duration of ICU stay in open surgery was 6 days [3], and in our series, it was only 1 day (mean 0.71, range 0–2 days).

Smithers et al. [21] reported median duration of hospital stay in their study as 14 days for open, 13 days for thoracoscopic, and 11 days for combined thoracoscopic and laparoscopic esophagectomy. Hulscher et al. [3] reported median days of hospital stay for transthoracic open esophagectomy as 19 days. In our study, median number of hospital stay was 8 days. Because of fewer complications, hospital stay was not extended in our series.

The results of our surgery appear to be far more superior to the published figures because of the following reasons—excluding patients with persistent T4a lesions after neoadjuvant chemotherapy and multistation bulky lymphadenectomy, ten times magnified view in robot, experienced oncosurgeons who are also doing robotic surgery for rectal and endometrial cancers with the same support staff, low pulmonary complication rate, taking liberal mediastinal pleural margin, and complete resection of thoracic esophagus up to cervical end in all our cases. From a systematic review, which included nine articles (130 cases) related to robot-assisted esophagectomy, it was concluded that robot-assisted esophagectomy was a feasible and safe technique [22]. In terms of short-

term oncological outcomes, robot-assisted minimally invasive thoraco-laparoscopic esophagectomy was at least equivalent to the open transthoracic approach for esophageal cancer [22, 23].

Conclusion

Robot-assisted three-stage esophagectomy has the benefits of minimally invasive surgery like less blood loss, decreased need of postoperative ventilator support, short-duration ICU stay, and low pulmonary complications resulting in short hospital stay, along with additional advantages of comparable operative time, low conversion rate, and short learning curve. Immediate oncological outcomes in terms of adequate lymphadenectomy and R0 resection are comparable to conventional open surgery. Therefore, robot-assisted three-stage esophagectomy is a safe and feasible technique for the treatment of esophageal cancer in selected patients. However, results of a randomized trial with long-term oncological outcomes (ROBOT trial) are awaited in this regard [10].

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval Institutional Review Board approval was taken. “All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.”

Informed Consent “Informed consent was obtained from all individual participants included in the study.”

References

1. Parkin DM, Bray F, Ferlay J, Pisani P (2005) Global cancer statistics 2002. *CA Cancer J Clin* 55(2):74–108
2. Mariette C, Piessen G, Triboulet JP (2007) Therapeutic strategies in oesophageal carcinoma: role of surgery and other modalities. *Lancet Oncol* 8:545–553
3. Hulscher JB, van Sandick JW, de Boer AG, Wijnhoven BP, Tijssen JG, Fockens P, Stalmeier PF, ten Kate FJ, van Dekken H, Obertop H, Tilanus HW, van Lanschot JJ (2002) Extended transthoracic resection compared with limited transhiatal resection for adenocarcinoma of the esophagus. *N Engl J Med* 347:1662–1669
4. Ruurda JP, van Vroonhoven TJ, Broeders IA (2002) Robot-assisted surgical systems: a new era in laparoscopic surgery. *Ann R Coll Surg Engl* 84:223–226
5. Dindo D, Demartines N, Clavien P (2004) Classification of surgical complications a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 240:205–13
6. Palanivelu C, Prakash A, Senthilkumar R, Senthilnathan P, Parthasarathi R, Rajan PS, Venkatachlam S (2006) Minimally invasive esophagectomy: thoracoscopic mobilization of the

- esophagus and mediastinal lymphadenectomy in prone position—experience of 130 patients. *J Am Coll Surg* 203(1):7–16
7. Noshiro H, Iwasaki H, Kobayashi K, Uchiyama A, Miyasaka Y, Masatsugu T, Koike K, Miyazaki K (2010) Lymphadenectomy along the left recurrent laryngeal nerve by a minimally invasive esophagectomy in the prone position for thoracic esophageal cancer. *Surg Endosc Other Interv Tech* 24(12):2965–2973
 8. Fabian T, Martin J, Katigbak M, McKelvey AA, Federico JA (2008) Thoroscopic esophageal mobilization during minimally invasive esophagectomy: a head-to-head comparison of prone versus decubitus positions. *Surg Endosc Other Interv Tech* 22(11):2485–2491
 9. Boone J, Schipper ME, Moojen WA, Borel Rinkes IH, Cromheecke GJ, van Hillegersberg R (2009) Robot-assisted thoroscopic oesophagectomy for cancer. *Br J Surg* 96(8):878–886
 10. van der Sluis PC, Ruurda JP, van der Horst S, Verhage RJ, Besselink MG, Prins MJ, Haverkamp L, Schippers C, Rinkes IH, Joore HC, Ten Kate FJ, Koffijberg H, Kroese CC, van Leeuwen MS, Lolkema MP, Reerink O, Schipper ME, Steenhagen E, Vleggaar FP, Voest EE, Siersema PD, van Hillegersberg R (2012) Robot-assisted minimally invasive thoraco-laparoscopic esophagectomy versus open transthoracic esophagectomy for resectable esophageal cancer, a randomized controlled trial (ROBOT trial). *Trials* 13:230
 11. Kim DJ, Hyung WJ, Lee CY, Lee JG, Haam SJ, Park IK, Chung KY (2010) Thoroscopic esophagectomy for esophageal cancer: feasibility and safety of robotic assistance in the prone position. *J Thorac Cardiovasc Surg* 139(1):53–59
 12. Biere SS, van Berge Henegouwen MI, Maas KW, Bonavina L, Rosman C, Garcia JR, Gisbertz SS, Klinkenbijl JH, Hollman MW, de Lange ES, Bonjer HJ, van Der Peet DL, Cuesta MA (2012) Minimally invasive versus open oesophagectomy for patients with oesophageal cancer: a multicentre, open-label, randomised controlled trial. *Lancet* 379:1887–1892
 13. Luketich JD, Pennathur A, Awais O, Levy RM, Keeley S, Shende M, Christie NA, Weksler B, Landreneau RJ, Abbas G, Schuchert MJ, Nason KS (2012) Outcomes after minimally invasive esophagectomy: review of over 1000 patients. *Ann Surg* 256:95–103
 14. Osugi H, Takemura M, Higashino M, Takada N, Lee S, Ueno M, Tanaka Y, Fukuhara K, Hashimoto Y, Fujiwara Y, Kinoshita H (2003) Learning curve of video-assisted thoroscopic esophagectomy and extensive lymphadenectomy for squamous cell cancer of the thoracic esophagus and results. *Surg Endosc* 17(3):515–9
 15. Ahlering TE, Skarecky D, Lee D, Clayman RV (2003) Successful transfer of open surgical skills to a laparoscopic environment using a robotic interface: initial experience with laparoscopic radical prostatectomy. *J Urol* 170:1738–41
 16. Somashekhar SP, Jaka RC, Zaveri SS (2014) Prospective randomized study comparing robotic-assisted hysterectomy and regional lymphadenectomy with traditional laparotomy for staging of endometrial carcinoma—initial Indian experience. *Indian J Surg Oncol* 5(3):217–223
 17. Rizk NP, Ishwaran H, Rice TW, Chen LQ, Schipper PH, Kesler KA, Law S, Lerut TE, Reed CE, Salo JA, Scott WJ, Hofstetter WL, Watson TJ, Allen MS, Rusch VW, Blackstone EH (2010) Optimum lymphadenectomy for esophageal cancer. *Ann Surg* 251(1):46–50
 18. Dantoc MM, Cox MR, Eslick GD (2012) Does minimally invasive esophagectomy (MIE) provide for comparable oncologic outcomes to open techniques? A systematic review. *J Gastrointest Surg* 16(3):486–494
 19. Hulscher JB, Tijssen JG, Obertop H, van Lanschot JJ (2001) Transthoracic versus transhiatal resection for carcinoma of the esophagus: a meta-analysis. *Ann Thorac Surg* 72:306–313
 20. Decker G, Coosemans W, Leyn PD, Decaluwe H, Nafteux P, Van Raemdonck D, Lerut T (2009) Minimally invasive esophagectomy for cancer. *Eur J Cardiothorac Surg* 35:13–21
 21. Smithers BM, Gotley DC, Martin I, Thomas JM (2007) Comparison of the outcomes between open and minimally invasive esophagectomy. *Ann Surg* 245(2):232–240
 22. Singh RK, Pham TH, Diggs BS, Perkins S, Hunter JG (2011) Minimally invasive esophagectomy provides equivalent oncologic outcomes to open esophagectomy for locally advanced (stage II or III) esophageal carcinoma. *Arch Surg* 146:711–714
 23. Clark J, Sodergren MH, Purkayastha S, Mayer EK, James D, Athanasiou T, Yang GZ, Darzi A (2011) The role of robotic assisted laparoscopy for oesophagogastric oncological resection; an appraisal of the literature. *Dis Esophagus* 24:240–250