Langenbeck's Archives of Surgery (2019) 404:353–358
https://doi.org/10.1007/s00423-019-01785-y

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Robot-assisted cervical esophagectomy (RACE procedure) using a single port combined with a transhiatal approach in a rendezvous technique: a case series

Jan-Hendrik Egberts[1] · Mark Schlemminger[1] · Charlotte Hauser[1] · Jan-Henrik Beckmann[1] · Thomas Becker[1]

Received: 15 January 2019 / Accepted: 31 March 2019 / Published online: 23 April 2019

Abstract
Background Difficulties in thoracic access and the risk of pulmonary complications are major problems in esophageal surgery. Transhiatal techniques have been described to avoid the thoracic approach, but their oncological radicality continues to be questioned. A combination of a cervical and transhiatal approach, however, appears promising. We describe the technique of a robot-assisted cervical esophagectomy (RACE procedure), combined with a transhiatal approach in a rendezvous technique.
Methods The da Vinci Xi® robotic system was docked in a single port technique via a cervical approach. The upper third of the esophagus and the surrounding lymphatic tissue was dissected thoracically. Subsequently, the system was docked abdominally to allow us to completely dissect the esophagus in the rendezvous procedure.
Results The patients ($n = 4$) suffered no trauma or injury to surrounding structures during the procedure, and sensitive structures were preserved. Almost no robot arm collision occurred, and the arms did not contact the patients' head or shoulders. No patient converted to conventional robotic-assisted transthoracic esophagectomy. Complications included anastomotic leakage ($n = 1$), transient palsy of the recurrent laryngeal nerve ($n = 1$), and pneumonia ($n = 1$).
Conclusions The cervical approach to esophagectomy allows comfortable preparation and facilitates transhiatal access, while the rendezvous procedure enables easy identification of the cranial dissection plane. The degrees of freedom of movement of the robotic instruments allow for precise and controlled preparation, and the latest technology minimizes the risk of robot arm collision in single-excision surgery. This combined, robot-assisted approach appears to be a promising procedure for esophagectomy.

Keywords Cervical esophagectomy · Robot assisted esophagectomy · RACE procedure

Introduction

A major problem in esophageal surgery is the thoracic access and associated risk of pulmonary complications. These may be due to the thoracotomy itself and/or the need for single lung ventilation. Therefore, a transhiatal approach is used in many centers. However, it is controversial whether this technique for the removal of the regional mediastinal lymph nodes achieves adequate oncological control [1]. For tumors in the middle and upper third of the esophagus, a radical esophagectomy with lymphadenectomy is necessary. Minimally invasive techniques are used to reduce access trauma to the thorax. In addition to a long learning curve and technical limitations, these techniques are associated with the need for single lung ventilation, as well as an elaborate prone or semi-prone positioning on the patient's side or abdominal positioning of the patient.

Reported techniques to avoid thoracic access include use of a transhiatal approach, which dissects the middle and lower mediastinum, combined with a transcervical mediastinoscopic approach for dissection of the upper mediastinum. The transcervical mediastinal dissection was suggested as feasible because of its equivalence to the conventional transthoracic

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00423-019-01785-y) contains supplementary material, which is available to authorized users.

✉ Jan-Hendrik Egberts
jan-hendrik.egberts@uksh.de

[1] Department for General, Visceral, Thoracic, Transplantation, and Pediatric Surgery, University Hospital Schleswig-Holstein, Kiel, Germany

approach in terms of the number of harvested lymph nodes and the frequency of laryngeal nerve palsy [2]. More recently, Fujiwara et al. reported the use of single-port endosurgery using a pneumomediastinum in the transcervical mediastinal dissection [3]. However, transcervical endosurgery is technically demanding due to the narrow surgical field and the limited mobility of conventional minimally invasive devices.

These limitations may be overcome using a surgical robot system. For example, the EndoWrist® (Intuitive Surgical, Sunnyvale, USA) allows almost unlimited freedom of movement for precise and stable preparation. We first carried out feasibility studies on cadavers, which showed that this technique is sensible and applicable. Subsequently, we successfully implemented the procedure in the clinic. In this report, we describe the technique and first clinical results of a robot-assisted cervical esophagectomy (RACE procedure) combined with a robot-assisted transhiatal procedure in a rendezvous technique.

Materials and methods

For the implementation of this procedure, we first learned how to best perform the individual surgical steps using cadavers in a medical training center (Medizin im Grünen, Wendisch Rietz, Germany). The following surgical steps were proven to be practicable.

Patient positioning, skin incision, and port placement from cervical access

The patient was positioned in a supine position, and the head turned to the right and slightly stretched. About two transverse fingers above the clavicle, the skin incision was made over a length of 5 cm. The sternocleidomastoid muscle was preserved and the left common carotid artery was prepared medially until the left part of the esophagus (which was marked by a gastric tube) came forward. Subsequently, the left side of the tracheal cartilage was exposed and pulled to the right to identify and preserve the left recurrent laryngeal nerve (RLN). Finally, the esophagus was prepared close to the wall in a circular fashion and a surgical tape was placed.

The esophagus and surrounding tissues, including the lymph nodes, were dissected bluntly until the upper thoracic aperture was reached and a small GelPort (Applied Medical, Rancho Santa Margarita, CA) was inserted. A pressure of 8 mmHg was then applied. Due to the small space of the operating field, it was essential to use a high-flow pumping system to achieve an even and stable operating field (Airseal®, DACH Medical Group, Germany).

The ports were positioned as follows. At the caudal pole of the GelPort, an 8-mm camera trocar was introduced with a 30° up-angled rigid scope. At the right and left edge of the GelPort, 8-mm trocars of the da Vinci® (Intuitive Surgical, Sunnydale, USA) trocars were introduced. Another 12-mm assist trocar was used at the cranial pole (see Fig. 1a). After targeting the da Vinci Xi® system (Intuitive Surgical, Sunnydale, USA) and precise adjustment of the arms, the following instruments were inserted: the right hand operated the monopolar scissors, the left hand, and the bipolar forceps (Fig. 1b).

Dissection of the upper third of the thoracic esophagus (Video 1)

The preparation began at the dorsal and left lateral margins of the esophagus. This was performed partly bluntly, partly with the monopolar scissors. Attention should be paid to the ventral and right-sided dissection of the esophagus. The pars membranacea of the trachea and the now ventrally located RLN must be identified and treated with care (Fig. 2a). Otherwise, the trachea serves as a guiding structure down to the carina to depict the subcarinal lymph node station and finally the pericardium (Fig. 2b, c). The dorsal preparation plane is the prevertebral fascia. The target structures are the thoracic duct, the azygos vein, the left-side pleura, and the aortic arch (Fig. 3a, b). There are no blocking structures in this preparation level. Small arterial vessels from the aortic arch to the esophagus can be safely coagulated with bipolar forceps. The number 7 lymph node and the lymph nodes adjacent to the RLN were dissected separately in a safe and comfortable setting. After reaching this dissection depth, the esophagus was sufficiently mobilized from the cranial portion to then proceed in the transhiatal rendezvous. Due to possible minimal pleural injury and consecutive pneumothorax, 20 Ch thoracic drainages were placed on both sides for safety reasons.

Transhiatal preparation and dissection (Video 2)

Subsequently, the robot was redocked for the abdominal part of the operation as described before [4]. The camera trocar was placed above the umbilicus, two robot trocars placed on the left side, and one robot trocar on the left side with another 12-mm working trocar (Fig. 4a). This was followed by intra-abdominal gastrolysis in the medial to lateral direction and DII lymphadenectomy, and then transhiatal mobilization of the lower third of the esophagus (Fig. 4b, c). Subsequently, the cervical esophagus was transected and the surgical specimen was harvested from a small abdominal skin incision. The gastric conduit was applied extracorporeally with a linear stapling device, and the conduit was lifted to the cervical incision via the retromediastinal route. The anastomosis was performed for the cervical esophagus and the conduit in terms of a hand-sewn end-to-side esophagogastrostomy. In addition, a feeding tube was inserted, as well as a chest tube

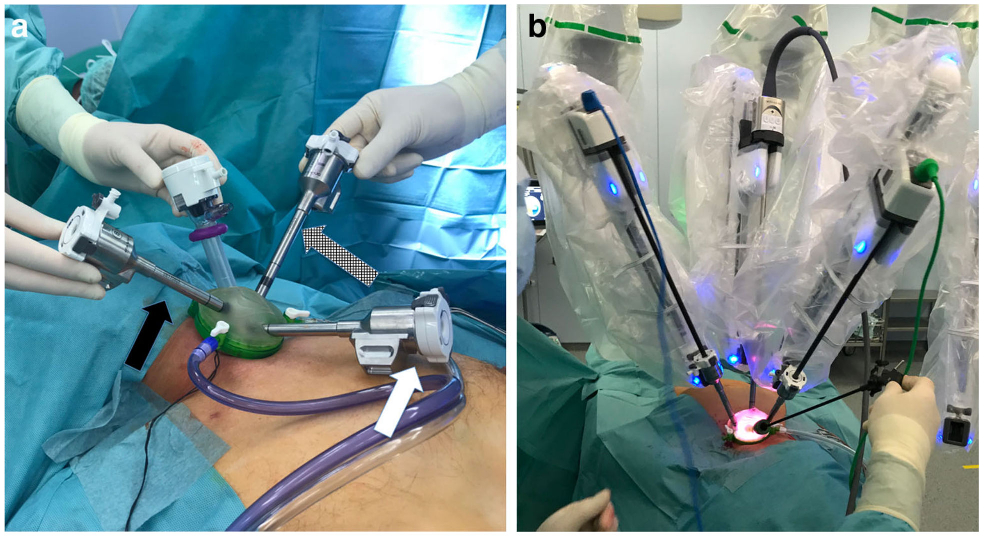

Fig. 1 **a** Cervical approach: Port placement: white arrow: 8-mm camera port (caudal position); black arrow: 8-mm robotic trocar for using the right hand; crosshatched arrow: 8-mm robotic trocar for using the left hand, 12-mm assist trocar. **b** Cervical approach: docked da Vinci Xi system. The table assistant sits at the head with caudal access via the assist trocar. **c** First view for the console surgeon. The thyroid gland is below the scissors, the esophagus is constrained (red band) with a view into the upper thoracic aperture

for potential mediastinal pleura damage. The postoperative situs is shown in Fig. 4c.

Patients

Between February 2018 and December 2008, four esophageal cancer patients underwent robotic assisted cervical esophagectomy as described above. Indications for this procedure were (i) histologically proven esophageal squamous cell cancer, (ii) a tumor clinically staged as T1–2 N0–1 M0, with no prior radiochemotherapy to the operative field. Clinical characteristics of the patients are summarized in Table 1.

Perioperative outcomes

Operation time, estimated blood loss, conversion to thoracic approach, postoperative complications, and length of stay were reported. Operation time for the cervical phase was measured from the first skin incision to the termination of the transcervical mediastinal insufflation.

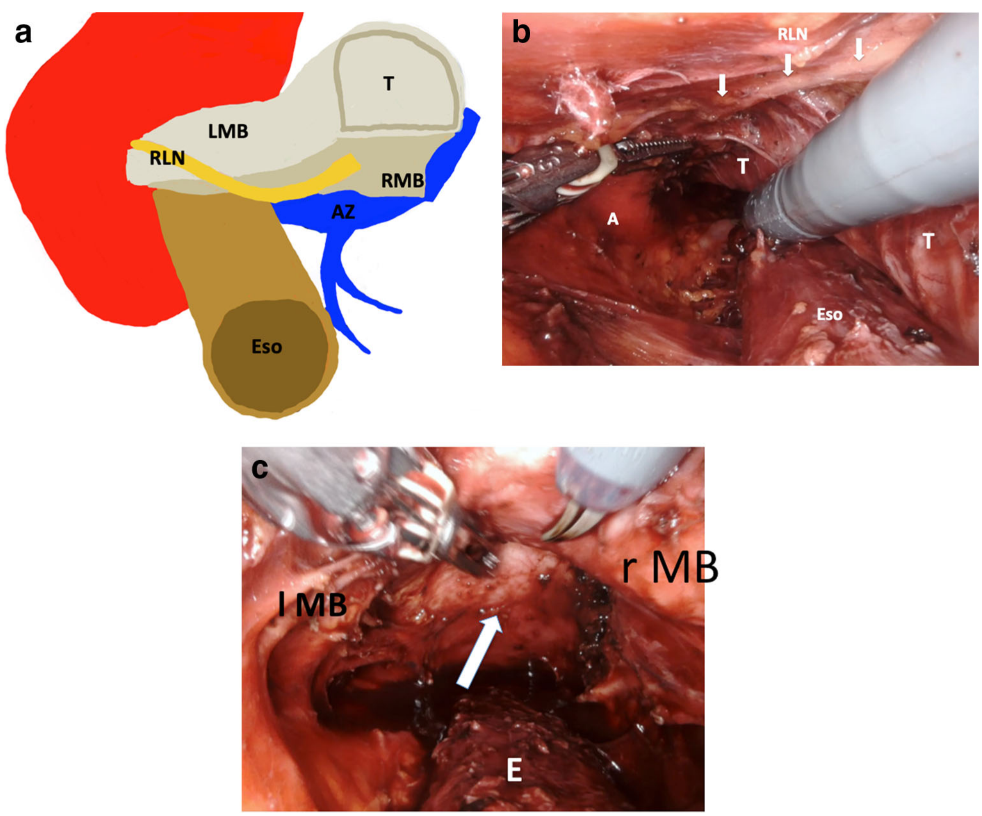

Fig. 2 Anatomical structures in the upper third of the mediastinum. *A* aorta, *T* trachea, *LMB* left main bronchus, *RMB* right main bronchus, *AZ* azygos vein, *Eso* esophagus. **a** Diagram of anatomical structures during preparation of the anterior esophageal wall. The trachea and the RLN is located anterioly, the aortic arch on the left side of the esophagus. **b** Course of the left recurrent laryngeal nerve. Note the prepared trachea (T) and esophagus (Eso). **c** View of the carina (C) and the right and left main bronchus. After removal of the subcarinal lymph node, the pericardium (white arrow) appears

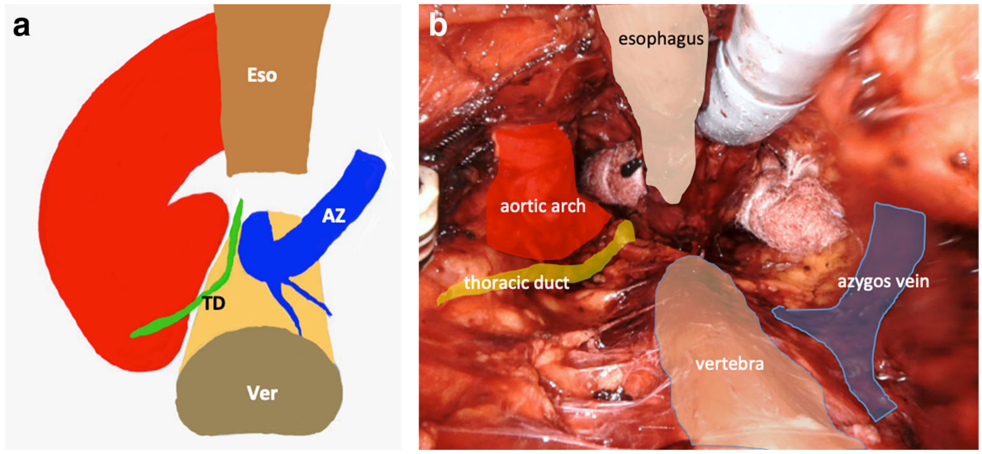

Fig. 3 Surgical view of the upper and middle mediastinum. Note that the esophagus is lifted and the dissection plane on the posterior esophageal wall. **a** The preparation plane is the prevertebral fascia. The target structures are the thoracic duct (TD), the azygos vein (Az), the left-side pleura, and the aortic arch (A). **b** Surgeon's console view

Results

In all cases, the RACE procedures were completed by a cervical robotic approach and a laparoscopic transhiatal dissection. The freedom of movement of the robot instruments through the setting was very good, and there were only a few arm collisions as the dissection was performed in the medium third of the esophagus. At no time did the arms contact the patients' head and/or shoulder.

There was no conversion to the conventional robotic-assisted transthoracic esophagectomy, and no adverse events closely related to RACE were observed. Duration of operation, estimated blood loss, and the postoperative course are listed in Table 2. Anastomotic leakage was observed in one case that resolved within 2 weeks by conservative treatment and cervical drainage. This patient developed also one transient palsy of the RLN that recovered within 6 weeks after surgery. One patient developed pneumonia that required a prolonged ICU stay (16 days). All patients underwent curative surgery, with pathologically negative circumferential resection margins.

Discussion

A major concern in esophageal surgery is the occurrence of pulmonary complications—whether as a result of

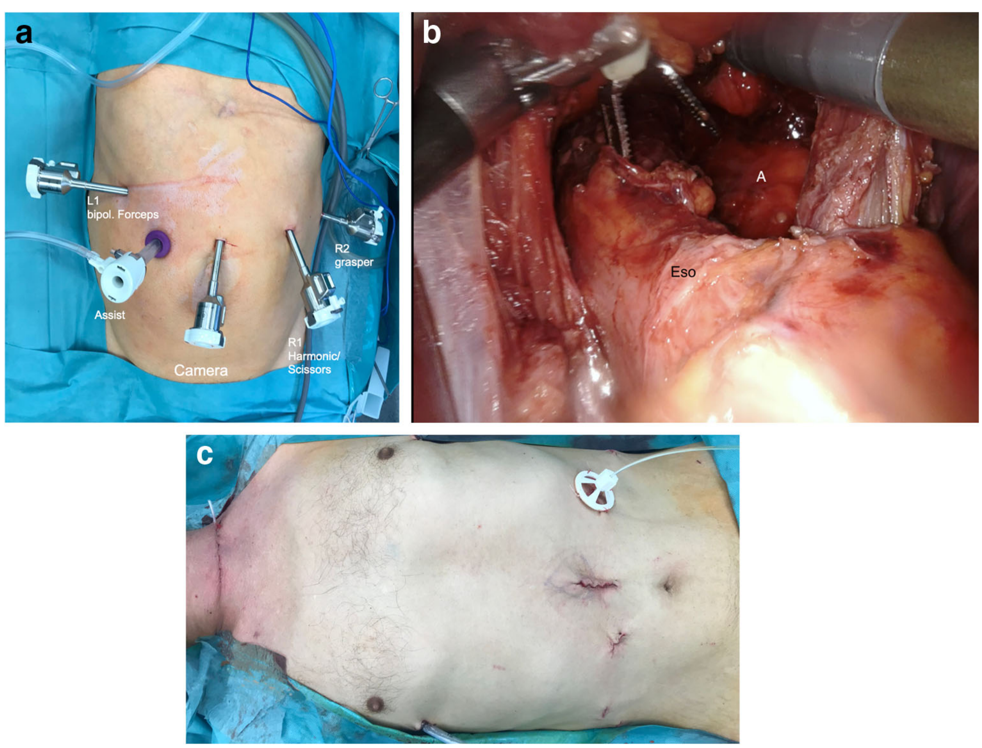

Fig. 4 Abdominal phase. **a** Position of the trocars. The surgeons operates with two right-handed instruments (scissors/harmonic scalpel and grasper) and one left-handed instrument (bipolar forceps). **b** Transhiatal dissection of the esophagus. The esophagus (Eso) is dissection up to the aarina. *A* aorta. **c** Postoperative situs. For safety considerations, thoracic drainage was performed during mediastinal pleural opening. A feeding tube (jejunostomy) was routinely applied.

Table 1 Characteristics of patients undergoing cervical robotic esophagectomy

Gender (male/female)	3/1
Age (years), median (range)	58 (54–73)
Height (cm), median (range)	178 (162–191)
Weight (kg), median (range)	62 (52–71)
Body mass index (kg/m^2), median (range)	22.3 (20.5–24.4)
Tumor location (upper/middle/lower)	2/2/0)
Clinical stage	
T1	2
T3	2
N (0/1)	1/3)
Prior radiochemotherapy (yes/no)	2/2
ASA I/II/III)/IV	0/1/3/0
Pulomary underlying disease (COPD, Empysema) y/n	4/0

surgical access or pulmonary damage due to single-lung ventilation during the dissection and reconstruction phase of the food passage. Therefore, in the past, there have been many surgical approaches to resect the esophagus without the need for thoracic access, including transhiatal and cervical approaches. However, these procedures reveal the limitations of conventional surgical devices. The reasons for this lie in the anatomical conditions, i.e., the narrow and difficult-to-access space in the upper mediastinum, and the relatively long and thus distant surgical operating areas. The use of the robot system enables these technical limitations to be overcome. The degrees of freedom of movement of the instruments allow for precise and controlled preparation so that operations can be performed in small and inaccessible surgical areas such as the upper mediastinum.

Table 2 Perioperative outcome of patients who underwent RACE (robotic-assisted cervical esophaegectomy)

	Median (range)
Operative measures	
Operative time (min)	
Cervical transthoracic part	154 (120–182)
Entire operation	344 (292–433)
Estimated blood loss (ml)	
Cervical transthoracic part	20 (10–30)
Entire operation	120 (20–180)
Length of stay (day)	18 (11–28)
Postoperative complications	
RLN palsy	1 (transient)
Chylothorax	1/4
Pneumonia	1/4
Anastomotic leakage	1/4
Re-surgery	1/4 (VATS ligation of thoracic duct)
Histological result	P1: ypT3yNo (2/14) P2: pT1b (sm3) pN0 (0/28)T2: P3: pT1b pN1 (1/24) P4: ypT3pN1 (2/32)
R0 resection margins	4/4

Due to our positive experience with the robot system using the transthoracic approach (RAMIE-procedures) in esophageal surgery, we realized that the system could sensibly be used for cervical dissection. During a stay of several days in a medical training center, we implemented and refined the technique step-by-step on human cadavers to guarantee safe transfer into the clinic.

It should be noted, however, that the access route to the upper mediastinum using the robot can be a technical challenge and the robot surgeon will require a certain amount of experience and expertise. Since this is a single-incision surgery, the distance between the trocars is naturally very small (approximately 3–4 cm) and clearly below the manufacturer's recommendations of 6 cm. Therefore, the risk of extracorporeal collision of the robot arms is high, and the procedure is currently only feasible with the DaVinci Xi System. Older systems, such as the Si and S systems, do not allow sufficient degrees of freedom of movement. Another observation is that the length of the instrument shaft in the narrow field may be associated with some risk of damaging the surrounding tissue. This might be a possible explanation for the transient palsy of the RLN in one patient, even though the RLN was detected and seen during the dissection phase and supposedly preserved. The technical developments in the next generation of robot systems, such as the Single Port System®, appear interesting in this context. Furthermore, a special generator for the pressure system is required to maintain the pneumomediastinum—similar to the transanal total mesorectal excision procedures, we connected the single port system to the Airseal generator (Airseal®, DACH Medical Group, Germany). However, it must be mentioned that this device might also be a reason for developing a respiratory problem in the first patient, since it has a very high volume throughput. A micro-injury of the mediastinal pleura might be a risk factor. On the other hand, the patients selected for this surgical procedure were all patients with a significant pulmonary disease. Therefore, we performed a prophylactic thoracic drainage in the subsequent patients after the first developed severe pneumonia postoperatively. A double lumen tube was also inserted in case of a possible conversion. With increasing experience using this technique, it would be conceivable to do without the double lumen tube, and to use a tubus for neuromonitoring of the RLN.

The cervical approach allows comfortable preparation down to below the carina with the infracarinal lymph node. This lymph node station and the course of the left main bronchus are the limiting structures in the transhiatal access. This set-up facilitates lymph node dissection of the left paratracheal nodes, which is sometimes difficult to achieve through the right transthoracic approach as the nodes are located behind the esophagus and the trachea. A bloodless surgical field was maintained without difficulty, and laborious clean-up manipulations with gauze or suction were rarely required. Furthermore, it appears possible to salvage the entire specimen via this incision so that the smaller incision at the abdomen is omitted.

For the cervical dissection, only two robotic instruments were used: monopolar scissors and a bipolar forceps. These instruments are also used for the abdominal part of the procedure, so there is no further cost increase when a robotic approach is planned for the abdominal phase. After cervical mobilization, the abdominal procedure is identical to the previously described abdominal set-up [4, 5]. The rendezvous procedure makes it easy to find the cranial dissection plane.

In summary, we describe the successful and easy to learn use of a single cervical port access using a DaVinci Xi System. It appears to be a promising procedure for esophagectomy, with prevention of thoracic trauma. The value of this technique could become relevant for the treatment of esophageal carcinomas in the middle and upper third. We were able to show that good oncological specimen with a sufficient number of lymph nodes could be removed from the defined lymph node station. Therefore, this technique could also be applied to patients who may not be suitable for surgical therapy due to other comorbidities.

Acknowledgements Thanks are given to Deborah Nock (Medical WriteAway, Norwich, UK) for editorial assistance.

Compliance with ethical standards

Conflict of interest Jan-Hendrik Egberts and Jan-Hendrik Beckmann are paid by Intuitive Surgery for proctoring surgical teams. Thomas Becker received a research grant by Intuitive SurgeryTM. The other authors have no conflicts of interest to declare.

Informed consent Written informed consent was obtained from patient for publication of this report and any associated images and videos.

References

1. Kutup A, Nentwich MF, Bollschweiler E, Bogoevski D, Izbicki JR, Hölscher AH (2014) What should be the gold standard for the surgical component in the treatment of locally advanced esophageal cancer: transthoracic versus transhiatal esophagectomy. Ann Surg 260:1016–1022
2. Watanabe M, Yoshida N, Karashima R, Sato N, Hirashima K, Imamura Y, Hiyoshi Y, Nagai Y, Iwagami S, Toyama E, Hayashi N, Baba H (2009) Transcervical superior mediastinal lymph node dissection combined with transhiatal lower esophageal dissection before transthoracic esophagectomy: a safe approach for salvage esophagectomy. J Am Coll Surg 208(4):e7–e9
3. Fujiwara H, Shiozaki A, Konishi H, Kosuga T, Komatsu S, Ichikawa D, Okamoto K, Otsuji E (2015) Single-port mediastinoscopic lymphadenectomy along the left recurrent laryngeal nerve. Ann Thorac Surg 100(3):1115–1117
4. Egberts JH, Stein H, Aselmann H, Hendricks A, Becker T (2017) Fully robotic da Vinci Ivor-Lewis esophagectomy in four-arm technique-problems and solutions. Dis Esophagus 30(12):1–9
5. Mori K, Yamagata Y, Aikou S, Nishida M, Kiyokawa T, Yagi K, Yamashita H, Nomura S, Seto Y (2016) Short-term outcomes of robotic radical esophagectomy for esophageal cancer by a nontransthoracic approach compared with conventional transthoracic surgery. Dis Esophagus 29(5):429–434