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NEW TECHNOLOGY

Transcervical minimally invasive esophagectomy using *da Vinci® SP™* Surgical System: a feasibility study in cadaveric model

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Abstract

Background This is a preclinical cadaveric study to investigate the feasibility of transcervical esophagectomy using a novel single-port robotic surgical system.

Methods A 40-mm cervical incision was created over left supraclavicular fossa. The novel *da Vinci® SP™* Surgical System was introduced through a wound retraction port. The mobilization of esophagus was performed using *da Vinci SP* from cervical, thoracic to abdominal segments. Lymph nodes were dissected en bloc with esophagus.

Results The transcervical esophagectomy with complete mobilization of the cervical, thoracic, and abdominal esophagus was completed in 60 min. The procedure was completed using the novel *da Vinci SP* Surgical System, which was introduced via the cranial side over the left cervical incision. No additional port was used for retraction and dissection, and the esophageal hiatus could be reached after complete transcervical dissection.

Conclusion This preclinical study demonstrated that transcervical esophagectomy is technically feasible and can be completed with the novel *da Vinci SP* Surgical System without additional ports or assistance. This will serve as an important step to the performance of robotic transcervical esophagectomy without the necessity of one-lung ventilation.

Keywords Transcervical esophagectomy · Robotic Assisted Minimally Invasive Esophagectomy · Da Vinci Robotic Surgical System · Esophagus

Carcinoma of esophagus is the eighth commonest cancer worldwide and sixth most common cause of cancer-related death [1]. Esophagectomy remains the standard treatment for esophageal cancer [2]. However, the morbidities and mortality associated with open esophagectomy remain significant. One of the most frequent morbidities from open transthoracic esophagectomy is pneumonia which amounts to 10–30% [3]. The development of minimally invasive esophagectomy (MIE) has significantly improved the clinical outcomes and reduced complications [4, 5], such as reducing the pain from the thoracic incisions and improving the pulmonary function as well as coughing efforts after esophagectomy. However, the incidence of pneumonia remains significant as transthoracic esophagectomy requires one-lung ventilation. On the other hand, transhiatal esophagectomy can achieve resection of esophagus without collapsing the right lung [6]. Thus far, clinical studies have shown that transhiatal approach is inferior to transthoracic approach in the number of lymph nodes dissected as well as trends towards worse 5-year survival [7]. One of the issues for laparoscopic transhiatal esophagectomy is the limited quality of exposure and space within the mediastinum during transhiatal dissection which limits the number of lymph node harvest. Recently, transcervical endoscopic approach has been reported, in combination with laparoscopic transhiatal esophagectomy, to achieve better quality of nodal dissection without transthoracic dissection and one-lung ventilation [8, 9]. We explore the feasibility and potential of using the

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recently developed *da Vinci® SP™* Surgical System (Intuitive Surgical, Inc, Sunnyvale, CA, USA) for performance of transcervical esophagectomy in a cadaveric model.

Methods

The MIE with transcervical mobilization of the whole esophagus was performed in a cadaveric model. Firstly, a transverse incision of 4 cm was performed just proximal to the clavicle. The sternocleidomastoid muscle was retracted anteriorly, and dissection was performed at the plane posterior to the sternocleidomastoid and anterior to the common carotid artery and jugular vein. After exposure of the cervical esophagus, a wound retraction device was inserted to seal the cervical wound (Fig. 1). The *da Vinci SP* patient cart was then docked from the right side of the operating table and the instrument arm was positioned from the cranial side while the single port was inserted through the wound retraction device (Fig. 2). One of the robotic instruments was used for retraction of the surrounding organs or tissue to expose the dissection field, while the other two instruments were used for dissection of the esophagus and surrounding lymph nodes using scissors. The mobilization of esophagus started from the cervical level, with positive identification of the left recurrent laryngeal nerve at the tracheoesophageal groove (Fig. 3). The mobilization of esophagus continued through superior mediastinum at anterior, lateral to posterior side of the esophagus with dissection of surrounding soft tissues. The subcardinal lymph nodes (station 107) and the bilateral bronchial lymph nodes (station 109R and 109L) were identified and dissected en bloc with the esophagus (Fig. 4). Further dissection continued over peri-esophageal (station 108, 110) and para-aortic nodes (station 112) until the diaphragmatic hiatus (station 111).

Fig. 2 Illustration on the settings and the *da Vinci SP* system

Results

Transcervical esophagectomy was performed in a cadaveric model. The novel *da Vinci SP* Surgical System was introduced over the cranial side, with slight turn of the

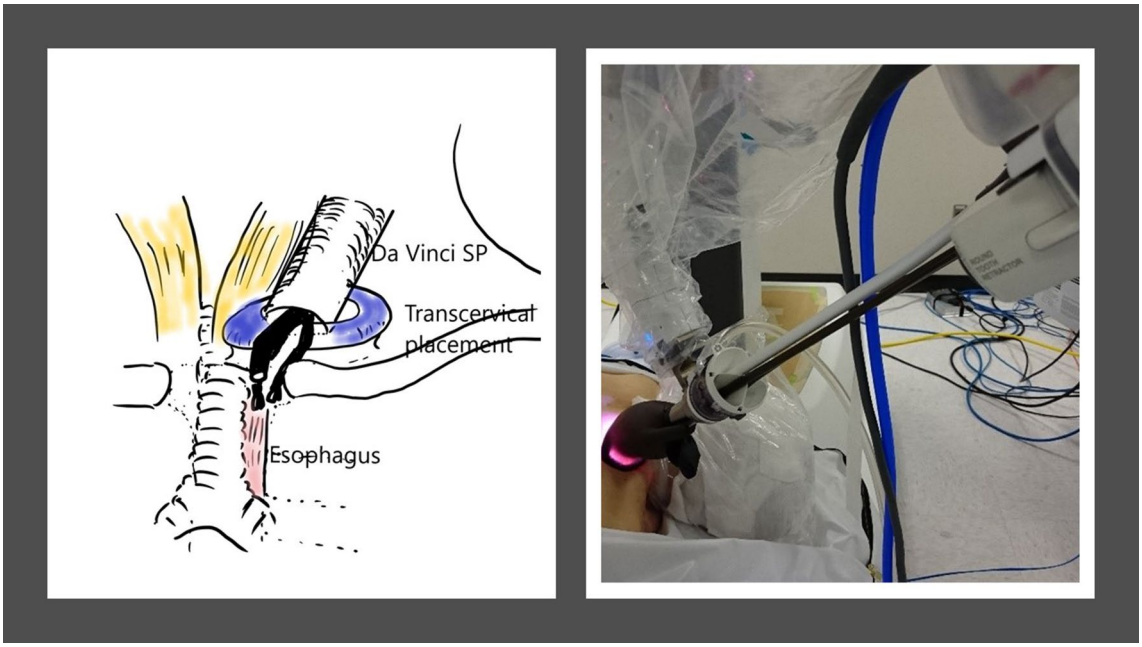

Fig. 1 The clinical setup for transcervical esophagectomy using *da Vinci SP* Surgical System through 40 mm incision and a single-port system

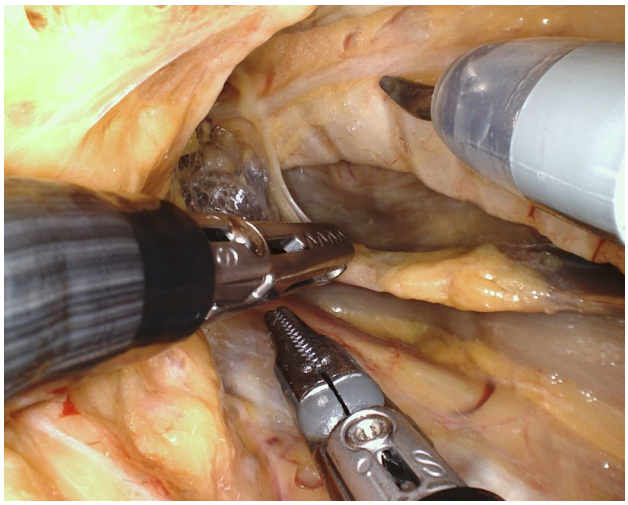

Fig. 3 Transcervical dissection demonstrating right recurrent laryngeal nerve at the tracheoesophageal groove

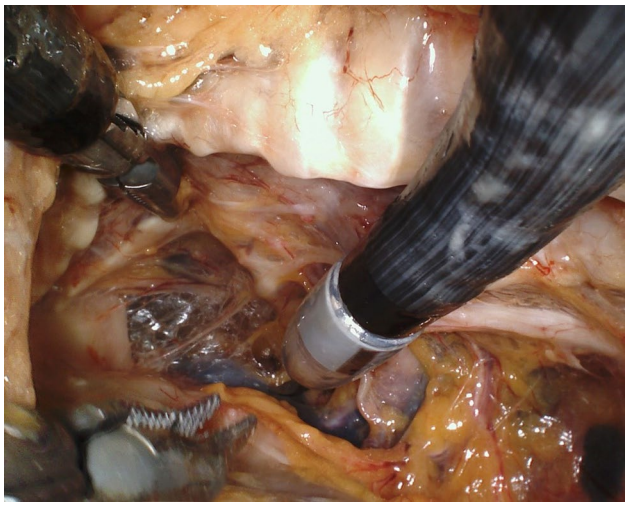

Fig. 4 Dissection at the subcarinal nodes with demonstration of the left recurrent laryngeal nerve

neck to the right side. The operative time for the transcervical esophageal mobilization was 60 min. The esophagus was fully mobilized from cervical, thoracic to abdomen segments. There was no injury to the surrounding organs, and the bilateral pleura were not bridged. Throughout the whole procedure, we did not need to change the position or readjust the *da Vinci SP* Surgical System. Additional assistance for retraction through an additional port was not necessary to complete the dissection to the diaphragmatic hiatus. Carbon dioxide insufflation maintained the mediastinal space, and there was no significant air leak during the procedure.

Discussion

From prospective and retrospective cohort studies, MIE can achieve similar operative results when compared to open esophagectomy [4–6]. Though there was a variation in the perioperative outcomes in terms of morbidities, generally MIE could achieve a lower rate of postoperative chest infection and significantly less pain. One of the major challenges in performing MIE is the exposure and dissection of the thoracic esophagus using rigid non-wrist instruments within the confined space of thoracic cavity. Several maneuverers need to be employed to enhance the exposure of thoracic esophagus for dissection, including placement of patient in prone position and use of low pressure CO_2 insufflation. Nevertheless, the dissection is hindered by use of rigid instruments in 2D laparoscopic view as the esophagus is deeply located within the mediastinum.

The development of robotic systems greatly enhanced the dissection within a confined body cavity. Prospective cohort studies confirmed the safety and advantages of Robotic Assisted Minimally Invasive Esophagectomy (RAMIE) for performance of transthoracic radical lymph node dissection [10–13]. Park et al. reported their experience in performing robotic-assisted thoracoscopic esophagectomy in 115 patients with a mean number of dissected nodes of 49.0 ± 1.9 [12]. The *da Vinci SP* Surgical System incorporates a stereoscopic camera and three 6 mm wristed instruments passing through a 2.5 cm portal. The robotic arm of the *da Vinci SP* Surgical System allows the instruments to be deployed within a confined cavity with sufficient dexterity and maneuverability [14]. From this current preclinical cadaveric study, robotic transcervical esophagectomy is feasible and safe with the use of the novel *da Vinci SP* Surgical System without the need to include an assistant port. The *da Vinci SP* Surgical System provided excellent exposure and visualization and enhanced the performance of mediastinal nodal dissection. The advantage of the transcervical esophagectomy or combined transcervical and transhiatal approach is the avoidance of opening the thorax and need for one-lung ventilation [8, 9]. This approach could possibly reduce the rate pulmonary complications which achieving comparable oncological clearance and lymph node dissection. The *da Vinci SP* Surgical System has significant advantages for performance of surgical dissection within a confined space. The *EndoWrist® SP* camera is equipped with a digital zoom function which allows better visualization of the organs while dissecting within the narrowed mediastinum.

This study has several limitations. First, it was a cadaveric study and cannot simulate the real clinical situation and surgical dissection, as well as bleeding and pulsation of the heart and aorta. Moreover, CO_2 insufflation is

necessary to maintain the space during dissection within the mediastinum. From our experience in performing transhiatal esophagectomy, there would be no significant sequelae related to this insufflation. However, the clinical effect of CO_2 insufflation via cervical approach could not be tested in the cadaveric model especially in the development of surgical emphysema. The current *da Vinci SP* Surgical System is equipped with diathermy for dissection only. The dissection and hemostasis would be improved through application of additional energy platforms like ultrasonic dissector.

In conclusion, this preclinical cadaveric model study served as a proof-of-concept experiment to demonstrate the feasibility of performing transcervical esophagectomy with the new *da Vinci SP* Surgical System. Further prospective clinical trial is warranted to confirm the safety and efficacy of this approach in performing combined transcervical and transhiatal approaches to achieve radical esophagectomy with the *da Vinci SP* Surgical System.

Compliance with ethical standards

Disclosures The current cadaveric model study was conducted at research laboratory of Intuitive Surgical Inc. at Sunnyvale, California, United States. Philip Chiu and Simon Ng received traveling sponsorship from Intuitive Surgical Inc. Samuel Au served as former systems analyst for Intuitive Surgical, Inc and led the algorithm development of *da Vinci*® Single-Site™ platform and was a contributor on the *da Vinci*® *SP*™ Surgical System platform.

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