Editorial

Robotic surgery for pulmonary segmentectomy

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Introduction

Although pulmonary segmentectomy for early stage of non-small cell lung cancer (NSCLC) has been debated regarding its effect on local recurrence and survival, it has several advantages including preservation of pulmonary function and decreased perioperative risk (1). Among anatomical pulmonary segmentectomies, segmentectomy for medial and anterior basal segments of lower lobe is one of the most challenging operations. Hiebinger *et al.* have performed bisegmentectomy for these segments via video-assisted thoracoscopic surgery (VATS) and Li *et al.* have performed it via robotic surgery (2,3).

Although VATS has several advantages over open surgery, it has limitations, including restricted ability of instrument maneuver, two-dimensional visualization, and loss of eye-hand-target axis. VATS has therefore been performed less commonly for pulmonary segmentectomy (4). Advantages of robotic surgery include magnified three-dimensional visualization, dexterity with angulation of the robot arm, and tremor filtration, thus affording better circumstances for thoracic surgery than VATS (4). Li *et al.* have reported surgical technique of robotic-assisted right medial and anterior basal segmentectomy for a 17×12 mm^2 ground glass nodule located in the right lower lobe. With robotic surgery, they could identify branches of basal pulmonary vessels and bronchus lying deeply in the parenchyma. Thus, they performed better dissection of lymph nodes. They concluded that robotic bisegmentectomy of lower lobe was safe and feasible (3).

With great interest in robotic pulmonary segmentectomy, we would like to share our experience of robotic surgery using four arms for lung cancer and discuss lobectomy and segmentectomy, VATS and robotic surgery, and techniques of segmentectomy with review of literatures.

Lobectomy and segmentectomy

In 1995, the Lung Cancer Study Group performed a prospect randomized trial to compare sublobar resection (segmentectomy or wedge resection) with lobectomy for clinical T1N0 NSCLC (3 cm or smaller in size) and found that sublobar resection resulted in higher death rate and locoregional recurrence rate. Based on these findings, lobectomy has been performed as a surgical treatment of choice for peripheral T1N0 NSCLC (1). Although lobectomy has better parenchymal resected margins than sublobar resection, resulting in decreased recurrence rate and death rate, it also causes loss of normal lung parenchyma, resulting in adverse effect on pulmonary function. Sublobar resection can preserve normal lung parenchyma. It can be performed for patients with poor pulmonary function.

Advances in clinical staging modality including computed tomography (CT) resolution have improved our ability to detect smaller sized lung tumor, leading to consideration of sublobar resection. Several studies have compared lobectomy with sublobar resection or segmentectomy for early stage of lung cancer. Khullar *et al.* have performed a retrospective study using National Cancer Data Base (NCDB) to compare operative results between lobectomy and sublobar resection for stage I NSCLC with a size of 2 cm or smaller. They found significantly improved overall survival in lobectomy and higher incidence of positive resected margins with inadequate lymph node dissection in sublobar resection (5). Subramanian *et al.* have performed a study using NCDB and found higher number of resected lymph node and lower rate of positive resected margins with lobectomy. Their results also showed that sublobar resection was associated with an increased risk of recurrence, but not with overall survival (6). Altorki *et al.* have compared survival of patients who underwent lobectomy or sublobar resection with early lung cancer manifesting as a solid nodule with a diameter of 3 cm or smaller in the International Early Lung Cancer Action Program (I-ELCAP). They found no difference in lung cancer survival between patients treated by lobectomy and sublobar resection (7). Ha *et al.* have retrospectively studied the patients with ground-glass opacity-dominant nodules measuring 2 cm or smaller who underwent lobectomy or sublobar resection. Their results showed no significant differences in the 5-year disease-free survival rate or overall survival rate (8). Tsutani *et al.* have examined patients with early stage of adenocarcinoma who underwent lobectomy or segmentectomy. They found that there were no significant differences in recurrence-free survival or overall survival between the two procedures, indicating that segmentectomy would be suitable for early stage of adenocarcinoma (9). Nomori *et al.* have examined the radicality of segmentectomy for clinical T1N0M0 NSCLC. Their criteria for radical segmentectomy included peripheral-type clinical T1N0M0 NSCLC, intraoperative negative sentinel node, and surgical margins greater than 2 cm. Based on their results of the recurrence and survival, they drew a conclusion that segmentectomy with systemic lymph node dissection and a sufficient surgical margin could be a radical treatment modality while preserving pulmonary function (10).

Thoracoscopic (VATS) and robotic surgery

VATS has several advantages over open thoracotomy surgery, including smaller surgical incisions, less postoperative pain, less perioperative complications, shorter length of hospital stay, shorter recovery time, and faster return to routine activities of daily living. However, it also has limitations, including use of the straight and non-articulating instruments, counterintuitive, limited visual field with two-dimensional visualization, and lack of scale down movements. On the other hand, robotic surgery system provides a magnified high-definition, three-dimensional visualization, intuitive, scale down movement, tremor filtration, and articulating robotic instrument that could overcome handicaps of VATS (11).

Oncological outcome

Because of the lack of long-term survival data, the number of lymph nodes removed has been used as an indirect indicator of oncological radicality (12). Bédat *et al.* have performed VATS segmentectomy in 100 patients with primary lung cancer and reported that the mean number of dissected lymph nodes from mediastinum is 11.8 (13). Song *et al.* have performed VATS segmentectomy in 41 patients with primary lung cancer and reported that the mean number of dissected lymph nodes from mediastinum is 13.7 (14). Toker *et al.* have reported that the mean number of dissected lymph nodes from mediastinum is 14.3 in 15 robotic segmentectomy patients with primary lung cancer (15). More long-term data of oncological outcome on lung cancer treated by robotic segmentectomy are required.

Bleeding control in robotic surgery

During the robotic surgery, the surgeon has no tactile sense or force feedback. The operation should be performed depending on visual sense alone (16). Because of these limitations, various degrees of vascular injury could occur during robotic surgery. We performed robotic lobectomy in 34 patients with lung cancer and experienced three cases of vascular injuries that were not adequately controlled by sponge compression. First, a pulmonary artery injury occurred at the end of vessel dissection. It was solved by prompt application of endovascular stapler. Second, an injury of the pulmonary artery occurred at the beginning of the dissection. It was compressed immediately with sponges and direct closure of the vessel was performed with a robotic suturing instrument. Third, the apical branch of the pulmonary artery was injured during right upper lobectomy. The bleeding could not be controlled by compression or direct suture with the robotic instruments. Eventually, conversion to thoracotomy was needed to complete the operation.

Operation time, cost and hospital stay

Deen *et al.* have retrospectively reviewed patients who underwent lobectomy or segmentectomy with VATS or robotic surgery. They showed that overall cost of robotic surgery was significantly higher than that of VATS and that VATS was associated with lower operation room time with similar length of hospital stay compared to robotic surgery (17). Our data with review of 87 patients who underwent lobectomy with VATS or robotic surgery also showed that the operation time of robotic surgery was significantly longer than VATS and the length of hospital stay after surgery was not significantly different between the two.

Technique of segmentectomy

3-dimensional computed tomography (3D CT) anatomy for segmentectomy

Importance of segmentectomy for surgeon is to understand a 3-dimensional anatomy of patients' pulmonary structures including artery, vein, and bronchus. Oizumi *et al.* have used 3-dimensional multidetector computed tomography (3D MDCT) images for surgical simulation during Segmentectomy Achieved by MDCT for Use in Respective Anatomical Interpretation (SAMURAI). SAMURAI is a segmentectomy technique in which the location of the tumor resection margin is estimated based on CT image while target blood vessels are determined in 3D (18). Shimizu *et al.* have performed segmentectomy based on 3D-CT angiography and bronchography (3D-CTAB). By recognizing branching pattern and spatial configuration of a patient's anatomy with 3D-CTAB, the surgeon could plan anatomical segmentectomy preoperatively by deciding which intersegmental veins should be used as landmarks, which artery/vein/bronchi should be dissected, and in what order (19).

Robotic surgery with four and three arms

Li *et al.* have performed robotic segmentectomy with three arms and a 4 cm utility incision. Through the utility incision, the assistant inserted suction tip and oval forceps to help retract the lung and expose the surgical field (3). Veronesi and Wei *et al.* have used a four-arm system and a utility incision or an assistant port. This fourth arm made it possible to retract the lung directly by the surgeon himself and better expose the operating field (20,21).

Identification of intersegmental plane

Li *et al.* have identified the intersegmental planes with re-inflation of the whole lung after transection of the segmental bronchus (3). However, during minimally invasive surgery, an inflated lung may obstruct visualization of the target segment. To identify intersegmental planes, indocyanine green (ICG) has been used transbronchially or intravenously in some institutions. Sekine *et al.* have injected ICG into the bronchus of target pulmonary segments after induction of general anesthesia. Target segments of the lung were identified using the ICG fluorescence endoscope. They could be removed by a stapler or electrocautery (22). Oh *et al.* have also used ICG. However, they injected ICG through the segmental bronchus after ligation of the pulmonary vessels and segmental bronchus (23). Pardolesi *et al.* and Ito *et al.* have injected ICG intravenously after division of the target segment bronchus, vein, and artery within the hilum. Nontarget segments were lit up while the target segment showed up as uncolored (24,25).

Conclusions

Robotic segmentectomy is a safe and feasible procedure for selected patients with early stage of NSCLC. If the cost is lowered and the operation time is improved through the learning curve, robotic surgery is likely to be a competitive modality to treat early stage of lung cancer. Additional studies are needed to determine effects of robotic segmentectomy on cost effectiveness, local recurrence, and survival.

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Footnote

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

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