Review Article

Robotic complex segmentectomies

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Abstract: Robotic complex segmentectomy (RCS) can be a useful technique for some patients with small early stage lung tumors. The procedural complexity makes it more technically demanding. Port placement and procedure of operation is described for the various segmentectomies. The precise tumor localization and identification of intersegmental plane will facilitate the procedure of RCS. Several studies have demonstrated safe and effective results of RCS.

Keywords: Robotic; complex segmentectomy; lung tumor; lung resection

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Introduction

In the past decade, the anatomical segmentectomy is increasingly been used in lung resection as the improvement of lung cancer screening techniques (1). Anatomical segmentectomy is more technically difficult compared to pulmonary lobectomy and preserve more pulmonary function, which is beneficial to patients with impaired pulmonary function (2). According to the complexity, anatomical segmentectomy can be divided into simple and complex procedure. Recently, robotic surgery has been widely used in various thoracic surgery but only several original studies have described the technique and outcomes of robotic complex segmentectomy (RCS).

Lobectomy and segmentectomy

Lobectomy with lymph node dissection remains the standard surgical treatment for patients with non-small cell lung cancer (NSCLC) for many years. In 1995, Lung Cancer Study Group (LCSG) (3) reported the long-term results of lobectomy versus sublobar resection (segmentectomy and wedge resection) in a randomized study with some limitations, which indicated that patients with sublobar resection have inferior overall survival and the local recurrence risk was three times higher compared to lobectomy group. However, with the recent advances in diagnostic technology, the precision of detecting small early-stage lung cancers (≤2 cm) have been improved (4). The ongoing JCOG0802/WJOG4607L (5), JCOG1211 (6), and CALGB140503 (7) trials will disclose the influence of segmentectomy on perioperative results and long-term prognosis. According to the European Society for Medical Oncology and National Comprehensive Cancer Network recommendations, segmentectomy may be recommended in highly selected patients unable to tolerate lobectomy as a compromised substitute. In addition, for a small peripheral lung tumor (≤2 cm) with non-solid or part-solid (component <50%) character, segmentectomy is also recommended.

The subdivision of segmentectomy

Depending on the complexity of the operation and the number and shape of intersegmental plane, segmentectomy can be divided into simple and complex procedure. Simple segmentectomy is defined as the procedure that create one or linear intersegmental plane, such as resection of the right

S^1, right S^6, left S^{1+2}+S^3 (upper division), left S^{1+2}, left S^4+S^5 (lingular division), left S^6. Complex procedure is defined as the more complex procedure that creates several or intricate intersegmental planes, such as resection of the right S^2, right S^3, right S^2+S^1a, right S^3a+S^2b, right S^8, right S^9, right S^{10}, right S^9+S^{10}, right S^6+S^8a, right S^6+S^{10}a, right S^6b+S^8a, left S^3, left S^{1+2}+S^3c, left S^{1+2}c+S^3a, left S^8, left S^9, left S^{10}, left S^9+S^{10}, etc.

Complex segmentectomy has been controversial due to the operation complexity and potential risk of increased complications. The surgeons concern about prolonged air leakage, decreased pulmonary function recovery, longer hospital stay and chest tube drainage due to the construction of several wound surface of intersegmental plane. During complex segmentectomy, precise identification and individual ligation of segmental bronchus, artery, and vein are involved to create several surgical margins, which will cause concerns about insufficient surgical margin distance. Till now, only several studies have evaluated the short-term outcomes of complex segmentectomy compared to simple segmentectomy. Kim *et al.* (8) reported only longer median operative time in the complex group compared to simple group, the other outcomes, including 30-day mortality, overall complications, prolonged air leakage, median surgical margin distance, number of dissected lymph nodes, margin relapse and postoperative pulmonary functions were nearly equivalent between the two groups.

RCS

Robotic procedure has not been widely used in complex lung segmentectomy so far, only several studies reported this technique and short-term outcomes. Li *et al.* (9) first reported the detailed technique of robotic approach to combined anatomic pulmonary subsegmentectomy (CAS) and the perioperative results in 16 patients. They performed the segmentectomy of right upper lobe (S^2b+S^3a, S^1b+S^3b, S^3+S^1b, S^2+S^1a, S^2+S^3a), left upper lobe (S^{1+2}+S^3c) and right lower lobe (S^9+S^8b), which concluded that robotic CAS is safe and effective in smaller (<2 cm) multisegment lung cancers. The robotics approach facilitates complex and challenging CAS but has prolonged operative times during early acquisition of skills. Although robotics CAS is more complex than simple procedure, the short-term outcomes appear similar between two groups. Zhang *et al.* (10) reported the learning curve of robotic anatomical segmentectomy in 104 consecutive patients including easy cases (right S^6; left S4+5, S^6), fairly difficult cases (right S^1, S^2, S^3, S^4, S^8, S^7+S^8+S^9+S^{10}, left S^1+S^2+S^3, S^1+S^2, S^3, S^8, S^8+S^9+S^{10}), and difficult cases (right S^1a+S^2, S^2b+S^3a, S^2+S^3a, S^1b+S^3, S^{10}, S^9+S^{10}, S^8+S^9, left S^8+S^9, S^6+S^8), which classified by Oizumi *et al.* (11). The learning curve of 104 cases was analyzed by RA-CUSUM method and divided into 3 phases: the initial learning phase (cases 1–21), the consolidation phase (cases 22–46); and the experienced phase (case 47–104). The learning curve analysis indicated that the operative time and blood loss decreased after phase I and the surgical competence was achieved at the 40th case.

Technique of RCS

Tumor localization in RCS

It is important to figure out a three-dimensional (3D) anatomical structures of pulmonary artery, vein, and bronchus before complex segmentectomy. Three-dimensional reconstruction CT combined with robotic surgery allows us to better identify the relationship between lesions of target segment and surrounding structures, which enable the surgeons to determine an adequate surgical margin, especially in complex segmentectomies. Li *et al.* (9) and Zhang *et al.* (10) used the reconstructed 3-dimensional images of CT angiography and bronchography based on enhanced thin-section (1 mm) thoracic CT. In addition, reoperative CT-guided hookwire localization was also used for lesions potentially elusive to surgeons or pathologists.

Robotic surgery with three or four arms

Some institutions (9,10,12,13) have used a 4-arm technique and an auxiliary port to perform the RCS. The surgeon can retract the lung directly and better expose the operating field by himself through the 4th arm. On the anterior axillary line, the arm 1 port (8 mm) and the auxiliary port (15 mm) are created in the 5th and 8th intercostal space, respectively. In the 8th intercostal space, the camera port (12 mm), arm 2 port (8 mm) and arm 3 port (8 mm) are also created on the midaxillary line, posterior axillary line and 2 cm from the spine, respectively. Li *et al.* (14) have used a 3-arm technique and a 4-cm utility incision to perform the RCS. Through the utility incision, several instruments can be inserted simultaneously, so the assistant can do all the retracting, dissecting and transecting procedure with one suction tip and one grasper, which can facilitate the surgery.

Identification of intersegmental plane

An adequate surgical margin is of great significance in lung cancer resection and identifying the intersegmental plane is a prerequisite to ensure adequate surgical margin in segmentectomy. It is challenging to identify accurate intersegmental planes in robotic segmentectomy, especially in complex segmentectomy with intricate intersegmental planes. Some institutions (9,10,14) used the re-inflation method to identify the intersegmental planes. After transection of the segmental bronchus, the whole lung is re-inflated, which, however, may affect the surgical field during minimally invasive surgery. So indocyanine green (ICG) has been used transbronchially or intravenously to identify intersegmental planes and appears promising. After injection of ICG, the fluorescence mode of robotic system is turned on and mediastinal and parenchymal tissue will appear green 30–40 seconds later. The coloration reaches maximum intensity after about one minute and fades slowly. Several different methods are used in ICG injection during surgery. Sekine *et al.* (15) and Oh *et al.* (16) injected ICG into the bronchus of target pulmonary segments, which were identified under the ICG fluorescence mode and removed by a stapler or electrotome. Pardolesi *et al.* (17) and Ito *et al.* (18) injected ICG intravenously after division of the target segment structures so only the target pulmonary segment was uncolored. Since lung palpation is not possible with the robotic technique, ICG facilitate the identification of intersegmental planes and achievement of adequate surgical margin.

Technique for tailoring complex demarcation

When dissecting the intersegmental demarcation, most thoracic surgeons empirically select the stapler or energy device randomly. Some studies have focused on a comparison between these two different methods (19). Cutting the intersegmental plane by using a stapler during segmentectomy might interfere with the expansion of the preserved lung, while the air leakage rate seems higher by energy device. A dimensional tailoring method has practical significance when dealing with deeply located segment with several intersegmental borders. Wang *et al.* (20) described a dissection technique including 3 key steps: excavating the "work-plane" (step 1), opening the "gate", (step 2) and tailoring along the demarcation (step 3). It can provide a cutting surface with a greater physiological shape and less curling of the edge, which can facilitate complex demarcation tailoring.

Discussion

The use of RCS for early-stage NSCLC is still controversial, although several studies has proved its safety and feasibility. With the shortened operation time caused by accumulated experience and reduced costs, the robotic procedure may be more competitive in the future. More studies are also needed to analyze the oncologic outcomes of RCS in larger population samples through long- term observation.

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