Review Article

Robot-assisted lung segmentectomies: where are we?

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Abstract: Minimally invasive lung segmentectomy is being more commonly performed, although the rule of sublobar resection as definitive management of non-small cell lung cancer (NSCLC) is still under debate. To date, anatomical segmentectomy should be considered a valid option for the treatment of patients with ground-glass opacity and small-sized early-stage NSCLC, not larger than 2 cm. The safety and feasibility of robotic pulmonary segmentectomy have been widely demonstrated, with comparable results in terms of perioperative morbidity and long-term outcomes compared to video-assisted thoracoscopic approach. Differently from other minimally invasive technique, Robotic platform could be integrated with new upcoming technology such as advanced three-dimensional (3D) images model and multimodal surgical navigation system. These integrated multimodal systems should improve surgical procedure from preoperative planning to intraoperative assistance.

Keywords: Segmentectomy; robotic-assisted surgery; lung cancer

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Introduction

The increasing adoption of lung cancer screening programs has resulted in the identification of a more considerable number of ground-glass opacity lesions and small (<2 cm), early stage, lung cancer. Several studies have recently shown that sub-lobar lung resection should be considered as an effective alternative to lobectomy for the treatment of non-solid (ground-glass opacity) and solid small (less or 2 cm) lung tumor (1,2).

It appears reasonable to consider anatomical segmentectomy the preferred approach for patients with stage I non-small cell lung cancer (NSCLC), when acceptable margins are obtainable, especially in elderly patients or when the performance status and cardiorespiratory function is reduced (3,4). In the attempt to offer a less invasive approach, video-assisted thoracoscopic segmentectomy (VTS) first and more recently, robotic-assisted segmentectomy (RTS) have been developed and progressively adopted by thoracic surgeons.

Studies comparing thoracoscopic segmentectomy with open segmentectomy have shown that VTS for stage I NSCLC is feasible and safe. The VTS approach is related with shorter length of stay, lower costs, reduced rates of overall complications, including cardiopulmonary morbidity and air-leaks. Thoracoscopic segmentectomy also appears to be associated with an equivalent survival rate compared to thoracotomy approach with several studies reporting 0% 30 days mortality with no difference in long-term outcomes (5-8).

Nevertheless, VTS still presents some potential limitations. The two-dimensional (2D) visualization, the lack of the eye-hand-target axis and non-ergonomic rigid instrumentations can lead to challenging dissection within the chest cavity. Therefore, thoracoscopic segmentectomy is usually performed by experienced surgeons in high volume centers.

Since it was first introduced at the beginning of this century, robotic-assisted thoracic surgery has progressively gained more and more popular among general thoracic surgeons (9). Robotic technology has been developed to overcome some of the limitations of video-assisted surgery. The three-dimensional (3D) visualization system, the increasing degree of motion and small-wristed instruments that replicate human wrist movements facilitate complicated dissection even in a remote area of the chest cavity.

The first series of robotic segmentectomy is reported by Anderson *et al.* in 2007 (10); since then, various canters have published their initial experiences. The report by Dylewski *et al.* (11) included 35 patients who underwent robotic segmentectomy with a lower rate of post-operative complication compared to robotic lobectomy (11.4% *vs.* 31%). Pardolesi *et al.* (12) reported a multicenter experience with similar complication rate (17.6%) and no 30 days mortality. In 2016 the most extensive series of 100 patients who underwent robotic segmentectomy was reported (13). The authors presented no conversion to open surgery (seven conversions to lobectomy), a median blood loss of 20 [10–120] mL, a median operative time of 88 minutes, no perioperative mortality and low rate of complications.

Long terms results of robotic segmentectomy have been investigated by Nguyen and colleagues (14). The authors retrospectively reviewed 71 patients who underwent RTS for early-stage NSCLC. Mean follow-up was 54 months (range: 2 months to 9 years). The 5-year lung cancer-specific survival for pathological stage I was 73%. Rate of local and/or mediastinal recurrence was 6% (4 out of 71 patients).

Based on these initial results, RTS appears to be safe, feasible and oncologically effective, although the equivalence or benefit between RTS and VTS is still a topic under debate in terms of functional and oncologic outcomes.

In 2015 the meta-analysis, reported by Ye and colleagues, evaluated perioperative outcomes of robotic-assisted surgery versus video-assisted thoracic surgery for early-stage lung cancer. The authors included eight studies; morbidity and perioperative 30-day mortality were similar between the two approaches. (morbidity P=0.605; 30-day mortality P=0.095) (15). More recently, Liang *et al.* (16) performed a systematic and comprehensive review using data from the latest studies to conduct a meta-analysis of perioperative safety, conversion rate and operative time between the two approaches.

The results of this study revealed that robotic approach is a feasible and safe alternative to VTS with low 30-day mortality and comparable postoperative complications. Moreover, RTS was found to have significantly lower rate of conversion to thoracotomy; however, the operative time was longer.

A randomized trial (NCT02804893) to compare robotic and thoracoscopic video surgery for stage I and II NSCLC is ongoing; this trial aims to evaluate intraoperative and postoperative complications, duration of surgery, number of lymph nodes harvested, immune response, pain and quality of life. The findings of this trial will provide more evidence regarding the use of RTS as an alternative to VTS for the treatment of early-stage lung cancer (17).

Regardless of the results of surgical outcomes, costs remain a critical issue that limits the widespread of robotic surgery. Previous studies have reported that the costs of lung resection performed with open thoracotomy to be more expensive compared to minimally invasive surgery. Nevertheless, RTS is less competitive than VTS. Deen *et al.* reported that robotic lung resection cost $3,182 more than video-assisted thoracoscopic approach: the higher cost was mainly due to the cost of robotic-specific supplies (18). Novellis and colleagues performed a retrospective single center analysis to compare the cost of open, robotic and video-assisted thoracoscopic surgery in patients with lung cancer. They estimated that cost of the robotic procedure was 13.5% higher than video-assisted and open procedures; however, the cost of robotic approach was associated with a profit margin of 18% for the institution (health public system reimbursement). Therefore, the significantly shorter length of hospital stays for robotic patients help to optimize resources and shorten waiting times (19).

Technical aspects and future perspectives

Anatomical segmentectomy is a more challenging procedure compared to standard lobar resection. Extensive knowledge and familiarity with segmental anatomy and possible anatomical variation are required to isolate and divide the appropriate segmental bronchi and vessels safely. Besides, performing segmentectomy with minimally invasive approaches adds a specific grade of complexity to the procedure. Improved dexterity and depth of visualization offered by robotic technology facilitate execution of more complex procedures, therefore allowing precise and safe anatomical hilar dissection.

The unclear delimitation of the intersegmental plane, the problematic assessment of small or non-palpable lesions and anatomical variation of the bronchovascular elements are potential technical difficulties encountered when performing robotic segmentectomy.

Several methods have been reported for identifying the actual intersegmental plane and ensure proper excision of the nodule with respect of oncological margins (8,20-22). However, the sensitivity of these methods is limited to lung conditions (emphysematous lung) and needed a skilled surgeon to perform.

Continues evolving technology has led to the development of advanced imaging techniques, integrated with the robotic system, that provide excellent assistance from preoperative planning throughout all the steps of the surgical procedure. Electromagnetic navigation bronchoscopy (ENB) utilizes electromagnetic technology to localize and guide endoscopic tools or catheters through the lung. A virtual, 3D bronchial map developed from chest computed tomography (CT) scan allows to navigate through the bronchial pathway and precisely localize the tumor. Geraci *et al.* recently reported the outcomes of a series of 245 consecutive planned RTS. The investigators used navigational bronchoscopy with indocyanine green (IG) to localize the nodule and administrated IG intravenously after pulmonary vessels ligation to identify the intersegmental plane. Lung nodule was identified in 80 cases (86%) and R0 resection was achieved in all 245 patients. Significant morbidity occurred in 3 patients, and there were no 30- or 90-day mortalities. The results of this study suggest that ENB together with IG administered both bronchoscopically and intravenously is an effective technique to identify the target lesion and delineate intersegmental margin (23).

Baste, and colleagues have evaluated the clinical value of the 3D image model for planning surgical strategies in patients scheduled for RTS. After performing a chest CT scan, a dedicated software reproduces the contours of all anatomical elements (arterial, venous and bronchial up to the fifth level of division) and create a 3D model.

The role of the 3D model is still under investigation. However, the main potential functions can be summarized as follow:

- ❖ Individual exploration of the all anatomical bronchovascular structures (Identification of anatomical variations).
- ❖ Simulate RTS (virtual resections up to the level of t independent segment).
- ❖ Volume calculation of each segment (calculate the impact on the predictive postoperative respiratory function).
- ❖ Simulation of segmental margins (evaluate the feasibility of the proposed procedure) (24).

Comments

Lung segmentectomy is gaining increasing interest as a diagnostic and curative procedure for centrally located lung lesions requiring surgical excision (NSCLC and metastatic lesions). It is considered an oncologically safe procedure for patients with ground-glass opacity and small solid NSCLC (≤2 cm). It also presents the advantage of preserving lung parenchyma with limited impact on pulmonary function.

Robotic anatomical segmentectomy has proven to offer a valid alternative to open and video-assisted thoracoscopic approach in terms of surgical and oncological outcomes. The introduction of recent technologies integrated with the robotic platform can advance the performance of robotic technology and improve the safety and oncological efficacy of more complex procedure such as sublobar resections.

Cost is still an issue; robotic procedures must reduce the specific supply cost and shorten the overall operative time, to become more economically competitive with video-assisted thoracoscopic surgery.

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Footnote

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