Editorial

How to decrease technical obstacles to difficult video-assisted thoracoscopic surgery segmentectomy?

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Based on the Lung Cancer Group Study, lobectomy is still considered the gold standard for early stage lung cancer management (1). However, the increased use of chest-CT screening program and detection of small nodules or ground glass opacities of diameter smaller than 2 cm have raised the question of the adequacy of sublobar resection.

Pulmonary segmentectomy is a parenchyma-sparing technique that is currently proposed for diagnosis of centrally located nodules or definitive treatment of metastases or early stage non-small cell lung cancer (2). Segmentectomy is also a valuable option for repeated surgery of multiple lung lesions. Many retrospective studies have actually suggested that pulmonary segmentectomy can achieve recurrence and survival rates comparable to those of lobectomy in patients with small (diameter <2 cm), peripheral tumors when adequate surgical margin and lymph node dissection are achieved (3-9). On the other hand, pulmonary segmentectomy is a technically more challenging procedure that requires individual dissection of segmental broncho-vascular structures and identification of the intersegmental plane to prevent incomplete resection and post-operative complications.

Initially performed by thoracotomy for bronchiectasis lesions only, pulmonary segmentectomies are now increasingly being carried out by video-assisted thoracoscopic surgery (VATS), for a growing number of indications. A recent systematic review concluded that VATS segmentectomy for early stage cancer presented at least equivalent morbidity, recurrence and long-term survival compared with open segmentectomy (10). Other retrospective studies have reported post-operative benefits in favor of the VATS approach with shorter length of hospital stay, shorter duration of chest intubation and lower post-operative morbidity compared to open thoracotomy (11). Our group recently published our initial results after the introduction of VATS segmentectomy and showed that segmentectomy by VATS can be realized safely with acceptable morbidity and low mortality (12). In terms of oncological outcome, two recent meta-analyses, including respectively 22 and 31 studies (13,14), reported similar overall survival and recurrence rates when comparing anatomic segmentectomy with lobectomy for small peripheral tumors up to 2 cm in diameter. In addition, a recent propensity-score matching study comparing thoracoscopic segmentectomy with thoracoscopic lobectomy showed similar short-term surgical results and oncological outcomes between the two procedures (8).

When anatomical segmentectomy is preferred over lobectomy, two elements impact the risk for recurrence: tumor size and adequacy of surgical margin. Both elements should be considered for the pre-operative planification of anatomical segmentectomy. Additionally, there should be no lymph node involvement and the extent of lymph node dissection and the number of lymph nodes removed should be at least equivalent when comparing anatomical segmentectomy and lobectomy for the management of lung cancer. This observation has been reported to be equivalent when comparing VATS lobectomy and segmentectomy

(15,16). Furthermore, segmentectomy has been reported to achieve higher lymph node dissection yield and higher nodal upstaging rates when compared to wedge resection in early stage lung cancer. Currently, a systematic dissection of segmental lymph nodes would be recommended instead of sampling or selective lymphadenectomy. This is particularly relevant when comparing wedge resection with segmentectomy, which requires an extensive hilar dissection and allows more adequate N1 lymph node harvesting and larger resection margins leading to a more complete and oncologically adequate procedure in case of lung cancer. It is expected that the publication of the final results of the two ongoing randomized trials (NCT00499330) and (JCOG0802/WJOG4607L) comparing VATS segmentectomy and lobectomy for peripheral non-small cell lung cancer of diameter <2 cm will shed more light on this issue and help to define the oncological safety of segmentectomy.

From a technical point of view, tumors considered for VATS segmentectomy should be confined to the anatomic segmental boundaries without crossing intersegmental planes. Multiple segmentectomies can also be an alternative to lobectomy when tumour is located across intersegmental plane. The anatomical singularity of each patient makes this type of resection challenging. Segmentectomies can be classified into typical and atypical based on the difficulty of the procedure (17). Typical segmentectomies include segmentectomy of the left upper lobe (trisegmentectomy or lingulectomy), superior segmentectomy (S6), and basilar segmentectomy. These are well standardized procedures, regularly performed by VATS and not prone to difficulties pertaining to anatomical variations or identification of intersegmental planes. In contrast, atypical segmentectomies include segmentectomies of individual segments of the upper lobe, middle lobe, or of basilar segments. Atypical segmentectomies of the lower lobes are technically feasible by VATS but remain challenging, especially since standardization reports are still lacking. However, this procedure is interesting because the greatest part of pulmonary perfusion and function is located in the lower lobe. This is particularly relevant for NSCLC patients with poor pulmonary function or for cases when lobectomy is not necessary, such as in patients with small nodules. The latero- and postero-basal segments (segments 9 and 10) of the lower lobes are probably the most challenging segmentectomies since vascular structures and bronchi are located deep in the parenchyma and division of two or more intersegmental planes is required. Furthermore, anatomical variations are very common in this region. Incorrect identification of vascular or bronchial structures and of the intersegmental plane may lead to potentially catastrophic complications or insufficient margins.

Many technical advances have been developed to facilitate segmentectomies: standardization of the approach, pre-operative radiological imaging with 3D reconstruction and identification of the intersegmental plane. Nomori *et al.* have described a technique involving extensive dissection of the fissure and identification of arterial and bronchial structures to S9 and S10 with extensive removal of all lymph nodes 12 and 13 (18). The two intersegmental planes between S6 and S9+10 and S8 and S9 should then be divided with electrocautery and inflation-deflation following the intersegmental draining veins. Combined S9 and S10 segmentectomy has been recently reported to be feasible by VATS, but remains challenging particularly in case of incomplete fissure (19).

Pre-operative imaging technologies, such as 3D pre-operative planning or intraoperative navigation are now becoming a part of general practice in thoracic surgery to improve an anatomical resection. These three-dimensional CT, which enables a 360° view of the entire lung can facilitate the identification of the hilar structures and improve the accuracy of the procedure. Several softwares are now available, allowing detection of >95% of vessels (20,21). This pre-operative preparation is essential particularly for atypical segmentectomies like S9 and S10.

However, in spite of the possibility to perform 3D segmentation pre-operatively, the intersegmental planes remain difficult to identify intra-operatively. The proper identification of the intersegmental plane might be a technical barrier during atypical lower lobes segmentectomy. Intra-operative assistance with indocyanine green (ICG) near-infrared angiography has recently appeared to help surgeons identify the intersegmental plane during segmentectomy (22,23). The vascular segmentation with ICG is easier and allows precise anatomical resection. It could also facilitate the surgical approach during VATS and improve the success and quality of the segmentectomy. We have recently reported our experience with intravenous injection of ICG during VATS segmentectomy. The near-infrared angiography allows the identification of the intersegmental plane with a success rate ranging from 88% to 100%. In addition, 10% of patients had modified intersegmental plane resection avoiding potential post-operative complication such as infarction or infection. The ICG angiography can also be easily and safely repeated once or twice if necessary.

The recent contribution by Zhu *et al.* furthers the development of simplification techniques for this atypical S9+S10 bi-segmentectomy by using a single direction caudal-to-cranial approach (24). The dissection is initiated from the inferior pulmonary ligament rather than the interlobar fissure in order to dissect and identify the different branches of the inferior pulmonary vein. After division of the segmental veins and dissection and removal of lymph nodes, the segmental bronchus becomes visible. Identification of the segmental bronchus allows clamping and inflation of the remaining lung to identify the intersegmental plane and confirm that the lesion is in the targeted segment. After transection of the segmental bronchus, segmental arteries can be divided. Finally, the intersegmental plane is demarcated by inflation/deflation and separated with staplers. This unidirectional approach allows a correct identification of the different broncho-vascular structures from caudal to cranial direction while preventing the troublesome dissection of an incomplete fissure.

There are two main approaches for VATS lower lobe segmentectomy: the trans-fissure and fissure-less technique. The trans-fissure technique requires an extensive dissection through the fissure to first individualize the lower lobe segmental arteries and then transect the bronchus and the veins. The dissection through the fissure allows a good identification of the segmental arteries but might increase the risk of air leak. When the fissure is incomplete, the operation may be difficult and conversion is inevitable in some cases. The fissure-less technique has originally been introduced to complete VATS lobectomies in cases where the fissure is hypoplastic (25). Initially described for upper lobes, it is now well reported for lower lobes, and allows progression from a single direction without back side of the lung. For lobectomies of the lower lobes, it allows caudal to cranial progression with division of the vein followed by the bronchus, the arteries and the fissure at the end. This approach has the main advantage to avoid unnecessary dissection through the fissure. Zhu *et al.* have successfully adapted this technique to all lobes and many segments including the difficult S9+S10 bi-segementectomies. This technique is certainly very helpful especially in cases with an incomplete fissure or when the access to the hilar structure is difficult from the fissure. Care should be taken however, to achieve a proper lymph node dissection of station 11 and 12 which may be more difficult as the fissure is not dissected, in contrast to the technique of Nomori or Xue.

There is little doubt that pulmonary segmentectomy by VATS will become the standard for small pulmonary lesions or early-stage cancer. Atypical segmentectomies are still challenging procedures, especially when performed by VATS. We wish to thank Zhu et al for their contribution to facilitate this approach. Their caudal-to-cranial direction technique will no doubt help surgeons to deal with complicated, atypical segments. In parallel, several developments such as pre-operative 3D reconstructions imaging or identification of intersegmental plane by ICG are investigated and may result in an improvement of the surgical procedure and even serve an additional educational purpose.

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Footnote

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