Anatomic thoracoscopic segmentectomy for early-stage lung cancer

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Abstract: Over the past 20 years, there have been significant advancements in thoracoscopic surgical techniques as well as in lung cancer screening protocols, which have identified greater numbers of smaller lung tumors (<2 cm) that are more frequently operable and curable. These advancements have led to new interest in the thoracoscopic (VATS) approach to segmentectomy. This article will discuss the outcomes and technical considerations associated with VATS segmentectomy.

Keywords: VATS segmentectomy; sublobar resection; thoracoscopic segmentectomy; lung cancer

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Over the past 20 years, there have been significant advancements in thoracoscopic surgical techniques as well as in lung cancer screening protocols, which have identified greater numbers of smaller lung tumors (<2 cm) that are more frequently operable and curable (1). These advancements have led to new interest in the thoracoscopic (VATS) approach to segmentectomy.

The VATS approach to segmentectomy for stage I NSCLC has been shown to be feasible and safe and has found to be associated with decreased perioperative mortality and equivalent or improved overall survival when compared to segmentectomy via thoracotomy (2-8). Several studies have also found the VATS approach to be associated with decreased length of stay, a trend in reduced costs and decreased rates of overall complications (e.g., reduced cardiopulmonary complications and chest tube duration length) (9).

Although VATS segmentectomy is a more complex procedure than the thoracoscopic lobectomy, several studies have demonstrated similar outcomes between the two approaches. For example, multiple studies have reported no significant differences between the two approaches with regards to operative time (8,10-14), overall complication rates (8,10-16), local recurrence rates (10-13,15,16), 5-year recurrence-free survival (10,11,16,17), and 5-year survival rates (8,10,11,16-18). In addition, studies have also shown that when compared to patients undergoing VATS lobectomy, patients who underwent VATS segmentectomy had similar (10,11,13,15) or reduced hospital length of stay (8,12,14).

With regard to mediastinal lymph node assessment, adequate lymph node evaluation appears to be feasible with the VATS approach to segmentectomy, but surgeon experience is critical, in particular in the case of the VATS segmentectomy. When comparing VATS segmentectomy to VATS lobectomy, three studies found no significant differences in lymph nodes harvested or nodal stations sampled (11,14,15) while one reported fewer lymph nodes harvested with segmentectomy (10). When comparing open *vs.* VATS segmentectomy, no significant differences in lymph nodes harvested were found in three studies (2,8,14), while another study reported decreased numbers of lymph nodes harvested via the thoracoscopic approach (5). In a subgroup analysis of segmentectomies from a national study comparing the completeness of lymph node evaluation during anatomic resection of primary lung cancer by open and VATS approaches, upstaging from cN0 to pN1 was seen in 4% among 170 VATS segmentectomies compared with 5.3% among 280 open segmentectomies (19). The investigators noted that differences in upstaging observed between the two approaches might have resulted from selection bias and equivalent nodal staging may be

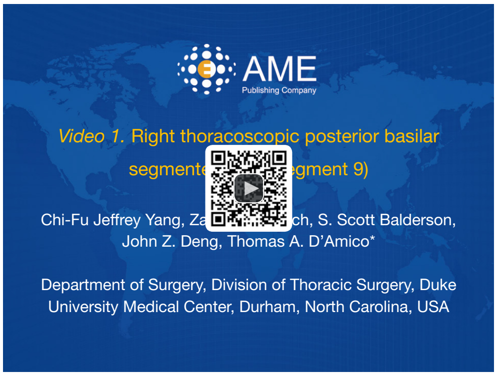

Figure 1 Right thoracoscopic posterior basilar segmentectomy (Segment 9) (35).
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possible with increasing experience with VATS. Further studies on lymph node assessment with open and VATS segmentectomy will be needed.

In addition to the traditional two-, three-, or four-port approach to VATS segmentectomy, a few small case series have reported results on the "totally thoracoscopic" or "complete VATS" technique for segmentectomy (20-27). This technique involves no access incision and retrieval of the specimen is through one of the port sites that is enlarged at the end of the procedure (28). A few case series have also reported results on the uniportal thoracoscopic segmentectomy, where the procedure is performed with one incision and through one port (29-32). Preliminarily, it appears that the totally thoracoscopic or uniportal approaches are feasible and safe, although both approaches are likely to be more technically challenging.

The typical (commonly performed) sublobar resections include lingula-sparing left upper lobectomy (trisegmentectomy), lingulectomy, posterior segmentectomy of the right upper lobe, superior segmentectomy, and basilar segmentectomy (single or multiple). The only absolute contraindication to performing a VATS segmentectomy is the inability to achieve complete resection. In a cancer operation, the parenchymal margin should be at least 2 cm, or the diameter of the tumor if larger than 2 cm (33,34).

Technical considerations

Thoracoscopic segmentectomy, similar to the open approach, is performed with dissection and individual division of segmental vessels and bronchi. Thoracoscopic segmentectomy begins with ligation of the segmental pulmonary vein for most segments, followed by either the bronchus or artery, depending on the segment. The parenchymal excision is accomplished by stapling in intersegmental fissures. In the situation where tumors are close to intersegmental fissures, bi- or tri-segmentectomy is appropriate. A protective bag is used to remove specimens.

Resection of the superior segment of the lower lobe is the most commonly performed single segmentectomy. Dissection starts with mobilization of the inferior pulmonary vein, to identify and isolate the vein from the superior segment. The venous branch to the superior segment is divided with a linear stapler, and this allows identification of the bronchial segment and dissection and removal of lymph nodes at levels 12 and 13. The bronchial segment may be stapled at this time, or dissection turned to the fissure, to identify and ligate the arterial branch to the superior segment. After both the bronchus and artery are divided, the parenchymal division is performed.

In the lower lobe, basilar segmentectomy (all 4 segments), sparing the superior segment, may be performed, although saving only the superior segment may be of uncertain benefit in some patients. Dissection is again initiated by mobilizing the inferior pulmonary vein, to identify and isolate the vein from the basilar segment, and to protect the superior segment branch. The arterial branches are then identified by opening the major fissure. Next, the bronchus is identified and ligated, after dissecting and removing regional lymph nodes on the bronchus. The accompanying video depicts a right basilar segmentectomy (*Figure 1*) (35).

In the upper lobe, the most commonly performed sub-lobar resections are lingulectomy and left upper lobe tri-segmentectomy. Lingulectomy is begun by opening the major fissure (preferably with an energy device or stapler to minimize post-operative air leaks). The lingular vein is then ligated, followed by ligation of the lingular bronchus and one or more lingular arteries (in either order). The parenchymal division between the lingula and the remainder of the upper lobe is easy to identify and staple. Upper lobe tri-segmentectomy is initiated by dividing the posterior pleura, allowing identification of the posterior segmental artery and facilitating anterior dissection to follow. Attention is then turned anteriorly, to accomplish dissection and division of the venous trunk, ascertaining that the lingular vein is preserved. Subsequently, the anterior apical trunk is dissected and divided; this is more easily performed if posterior dissection has previously been performed thoroughly. Subsequently, the tri-segmental bronchus is dissected, removing lymph nodes at levels 10, 11, and 12, followed by division. Once again, the parenchymal division between the lingula and the remainder of the upper lobe is easy to identify and staple

There continues to be debate regarding optimal techniques used to complete segmental division. In most cases, the segmental boundaries are relatively apparent using the landmarks of the dissected hilar anatomy. A commonly used technique to demonstrate the segmental plane involves temporary re-inflation of the ipsilateral lung after bronchial ligation to demarcate the plane (33). An alternative approach is to detect the intersegmental plane by partially inflating the segment of interest using selective jet ventilation during bronchoscopy, after single lung ventilation has been achieved (36).

There are limitations to lung inflation techniques particularly in cases of severe emphysema, where lungs can easily overinflate, leading to obscured surgical views (37). Another option for visualization not involving lung inflation is one that relies on infrared thoracoscopy with indocyanine green injection to visualize adjacent lung segments (37-40). Recently, a new method using methylene blue injection into the bronchus of the target pulmonary segments has also been introduced (41).

To assist the technical completion of segmentectomy, multi-detector row computed tomographic (MDCT) angiography is sometimes used to assess the relationship of the pulmonary tree with the tumor, to assist with pulmonary vessel isolation and to determine the resection line (25,42).

Localization of small tumors in a segment that are less than 1 cm in diameter and not immediately subpleural may be difficult. Localization techniques include using local injection of radiotracer (43), wire hook and coil markers (44,45), radiopaque markers using intraoperative fluoroscopy (46,47), and navigational bronchoscopy with dye injection (48). Successful localization may also be achieved in the majority of patients without these techniques (33).

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Footnote

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

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