Although the Lung Cancer Study Group published worse outcomes in patients with non-small cell lung cancer who underwent sublobar resection, these data are fairly old and not reflective of the current patient population or surgical techniques. With the change in lung cancer pathology over these past few decades, our increased understanding of lung cancer and the era of screening for lung cancer, video-assisted thoracoscopic segmentectomy will likely play a greater role in the management of our patients.

Operative Techniques in Thoracic and Cardiovascular Surgery 20:162-175 © 2015 Elsevier Inc. All rights reserved.

KEYWORDS VATS, segmentectomy, technique, lung cancer

Introduction

Since its development in the 1990s, video-assisted thoracoscopic surgery (VATS) has become an established method for the minimally invasive resection of lung pathology. Minimally invasive techniques have proven to cause less pain, less blood loss, decreased chest tube duration, shorter lengths of stay, more rapid return to daily activities, less impaired pulmonary function, improvement in compliance with adjuvant chemotherapy, and equivalent oncologic results.

A number of studies have aimed to define the indications for nonanatomical (wedge) resections, anatomical (segmentectomy) resection, and lobectomy for non-small cell lung cancer (NSCLC). However, many studies are flawed making interpretation of the data challenging. Currently, there is an ongoing phase III randomized trial of lobectomy vs sublobar resection for peripheral NSCLC that will hopefully provide clarity. The improvement of high resolution computed tomographic (CT) imaging and reconstruction has increased the detection of early (<2 cm) stage lung cancer and therefore highlighted the role of VATS segmentectomy for the treatment of primary lung lesions and metastatic disease. The focus of this article will be on VATS segmentectomy, specifically superior and basilar resection, background, and indications followed by a detailed description of the operative technique.

Thoracoscopic segmentectomy (sublobar resection) is defined as the removal of a segment of the pulmonary lobe with individual vessel ligation without the need for thoracotomy or rib spreading. Given vascular variation among patients, segmentectomy is considered technically more difficult than a lobectomy or wedge resection and should be done by experienced thoracic surgeons. Anatomically, Ewart first described the bronchopulmonary segment and its associated vasculature in 1889. It was not until 1939 when the first sublobar resection of the lingular segment was done for bronchiectasis. The success in infection control from this procedure led segmentectomy to be traditionally reserved for bronchiectasis, tuberculosis, and only in select patients with NSCLC. However, with the development of increasingly potent antibiotics and effective tuberculosis treatment, the benefit of segmentectomy has now been focused for resection of lung lesions.

Segmentectomy was used for patients with a variety of primary lung cancers until 1995 when the Lung Cancer Study Group by Ginsberg and Rubenstein demonstrated that sublobar resection for tumors <3 cm in size resulted in increased locoregional recurrences compared to lobectomy. As a result of this, lobectomy has remained the standard treatment for patients with resectable NSCLC. Meanwhile, segmentectomy has been reserved for select patients with small (<2 cm) tumor size and compromised cardiopulmonary function that would otherwise be unable to tolerate a full lobar resection.

Lung cancer continues to be the leading cause of cancer-related deaths in developed countries. CT screening programs have now increasingly detected early-stage lung cancer that may be amenable to segmental resection, hence the importance of learning and implementing this technique.

It is equally important to note the benefit of segmentectomy in infectious or inflammatory lung disease. Mitchell et al reviewed 171 patients from 2004-2010, who underwent VATS lobectomy or segmentectomy for bronchiectasis...
with or without cavitary lung disease after adequate antimicrobial therapy. Technically, segmentectomy for infectious etiology poses a different set of challenges than for oncologic resection. Even if the patient has not had prior thoracic surgery, pleural adhesions are commonly encountered surrounding the affected lung segments. Also, in the setting of inflammation, the bronchial circulation will be hypertrophied making blunt dissection without cautery or clipping challenging. Lastly, inflammation of the lung parenchyma can make staple closure of the intersegmental lobe difficult (Figs. 1-9).

Defining the segmental anatomy can be a difficult task even for the experienced surgeon. CT angiography and 3-dimensional processing of CT images can be used preoperatively to define the course of the segmental vessels and therefore minimize error. Solid models of the bronchopulmonary segment using a 3-dimensional printer from CT images can also be constructed but tend to be costly.

Segmentectomy of the lower lobe, including the superior segment and basilar segments, en bloc, is technically often the most straightforward segmentectomy to perform for the same reasons that lower lobectomies are often the most straightforward lobectomy to perform. This is because the anatomic separation of the structures to be divided is the most obvious, vascular injury is less likely and control of an injury is technically easier. Because the basilar segmental artery and bronchus are anterior, relative to the superior segmental artery and bronchus, a basilar segmentectomy is also typically more accessible with an anterior thorascopic approach.

The following illustrations and discussion will focus on highlighting the anatomic differences between the right and left sides as well as strategic maneuvers to facilitate the dissection when needed.
Figure 1 Concealed anatomy. Before starting a segmentectomy, one should have a concrete mental model of the 3-dimensional view of the hilar structures from their origins to the more distal branching. One should be able to envision the dissection as one proceeds through the anatomy sequentially dividing the appropriate structures. This is critical for a safe successful operation and is particularly true when inflammatory lymph nodes or other pathology may complicate the resection, requiring alternative approaches.

Although the anatomy of the right and left lower lobe may roughly mirror one another, there are subtle differences that make certain aspects of each segmentectomy more or less favorable technically. We will try to highlight these differences.

The operation for both superior and basilar segmentectomy, right and left sides, proceeds in a similar fashion with dissection, ligation and division of the artery, bronchus and vein, typically in that order. These structures course together. However, it is important to recognize if one aspect of the operative plan becomes too challenging, consider aborting the plan and pursuing an alternate strategy, vein before bronchus or vein first, etc. As many texts have highlighted standard segmentectomy as a technique, we have attempted to describe some of the specific challenges and alternative options.

(A) Right: obscured right sided anatomy of the lower lobe. The segmental artery bronchus and vein course in proximity to one another
Figure 1 Continued (B) Left: obscured left sided anatomy at the interlobar fissure. Note, the biggest difference between right and left is the proximal bronchial anatomy and location of the superior segmental artery.

Positioning: when performing VATS segmentectomy of the lower lobe, either on the right side or the left side, the lateral decubitus position is used. However, we use an important modification to this positioning. The anterior axillary line is rotated to be the highest point on the patient. This will give a more anterior exposure of the chest wall and of the hilum. This allows for the utility port, as well as anterior port to be placed where the intercostal spaces are wider. The ipsilateral elbow is opened up so that the axilla is exposed and the shoulder kept as posterior as possible to keep the edge of the latissimus posterior. On the left side, depending on the patient’s anatomy, sometimes the pericardial sac may interfere with the dissection. In this case, we will place a stay sutures on the pericardium pulling the traction suture through the anterior inferior port site to lessen the interference.
Utility port over, or just below the fissure

Anterior inferior Port site in 7th or 8th intercostal space

Posterior 5mm Port 2 or 3 cm below scapula

Figure 2 For the approach, we use the standard anterior approach with 3 incisions. An inferior anterior 10 mm incision is placed in the seventh or eighth intercostal space in the anterior axillary line. Next, the posterior port 5 mm incision is placed about 2-3 cm inferior to the posterior border of the scapula. The utility port is placed, once the camera has been inserted, just below the fissure. This is typically a 3 cm incision. Here one errs on the rib space below the level of the fissure so that the instruments are working in line with the camera. For the utility port, once the skin incision is made, the serratus fibers are split and the latissimus spared. We use a soft tissue retractor especially in obese patients to facilitate entry of instruments into the chest. Once the camera is placed within the pleural cavity, it is inspected for presence of pleural, mediastinal, or nodal involvement that would otherwise be a contraindication for continuing a sublobar resection.

If the fissure is favorable, we usually start there. The pleura overlying the vessels is divided. However, if the dissection becomes tedious, we might do some posterior hilar dissection, or divide the inferior pulmonary ligament to take a “break” from the more challenging part of the operation. This is particularly true for patients with a concomitant diagnosis of sarcoidosis or histoplasmosis where the lymph nodes may be adherent to the vessels. It is important to realize if you are not making progress, to work somewhere else for a while and then go back to the challenging area. In this fashion, all of the anatomy will eventually reveal itself and it keeps frustration with the operation at bay.
Figure 3 The pleura and parenchyma overlying the intrafissural pulmonary artery is divided and the segmental vessels are identified. When the fissure is incomplete, the location of the underlying artery can be identified by looking at the parenchyma carefully and watching for the pulse of the vessel. We then divide the parenchyma overlying the vessel and dissect the vessels completely. We start this dissection with hook cautery to divide the pleura. For parenchymal division, we will continue to use the hook or bipolar sealing device. For incomplete fissures, this technique works very well and we have found minimal air leaks in patients without severe emphysema. There is also minimal bleeding with this approach. Also, as one progresses in performing a variety of segmentectomies, dissection of the parenchyma becomes necessary to define the anatomy of the underlying bronchovascular structures, even when one starts the dissection from a central hilum. Depending on the trajectory and individual patient's anatomy, we typically use a stapler for the basilar segmental artery placed through either the anterior camera port utility port to minimize intercostal nerve trauma by placing the stapler through the more narrow posterior intercostal spaces. For the superior segmental artery, given the size, we will use a clip, tie or sealing device as an alternative to a stapler.
Dissection of the intraparenchymal lymph nodes during dissection of the bronchovascular structures will facilitate ligation and division of these structures. On the left side, interlobar fissure dissection reveals the basilar segmental artery just distal to the lingular artery. More commonly, there is variable branching here. From the anterior view, the location of the bronchus is obvious, coursing under the artery.
Completion of the fissure between the superior segment and upper lobe can facilitate use of the staplers, in particular on the bronchus that lies deeper towards the hilum.

Strategies to facilitate completing the fissure include reflecting the lobe anteriorly and dissecting out the bronchus intermedius on the right side. This will facilitate creation of the window from the posterior aspect of the superior segmental artery through to the posterior space between the take-off of the upper lobe bronchus and bronchus intermedius, allowing division of the fissure to facilitate ligation and division of the bronchus.
On the left side, we find the superior segmental bronchus to be at a challenging angle for an anteriorly placed stapler through the fissure, as it has a more posterior trajectory given the rotation of the lower lobe, because of the heart in the left chest. Another obstacle is the aortic arch. Thus, again one can approach it from the posterior aspect reflecting the lower lobe anteriorly. We have found this to be the quickest direct technique. The camera is moved to the posterior port and the stapler articulated to ligate and divide the superior segmental bronchus.

For the basilar segmental bronchus, the fissure between the middle lobe and lower lobe or lingula and lower lobe has usually already been divided so the use of a stapler here is technically easier.

Vein: division of the vein typically comes after the bronchus. We like this sequence for the basilar segmental vein for specific reasons: (1) Division of the basilar segmental vein before the artery can lead to congestion of the basilar segments, making the dissection slightly more challenging. This is not true of the superior segmental vein. (2) Division of the vein after division of the artery and bronchus provides a clear image of the venous anatomy preventing inadvertent injury.
Figure 7  Right sided view: as an alternative strategic approach to bronchial and arterial dissection, for basilar segmentectomies, one may proceed with initial division of the basilar segmental vein from the inferior aspect of the hilum. This will allow one to lift the lower lobe in a cephalad direction, and identify the artery and bronchus from their most central hilar position. This is rarely necessary however, when needed, one should be familiar with the orientation of the anatomy.
Superior segmental bronchus
Superior segmental vein
Divided SS artery
RLL
RML
RUL

Figure 8 Superior segmental vein. (A) Right: one option for identifying the superior segmental vein is through the bed of resection of the bronchus, just proceeding posteriorly.
Figure 8 Continued (B) Left: another option, is from the posterior view as it joins the basilar segmental vein to become the inferior pulmonary vein.

Given the more anterior location of the basilar segmental vein, this is technically typically easier than the superior segmental vein as the approach is from the anterior view.
Figure 9 Once the bronchovascular structures have been divided, division of the parenchyma between the superior segment and basilar segments comes last. This can, at times, be the most challenging part of the case. It is important to recognize that the lower lobe is a pyramid and resecting either the top or bottom is benefitted by the creation of a 3-dimensional plane. The staplers that we use function in 2-dimensions but the plane that we need to create is in 3-dimensions.

To do this, division of the parenchyma is best approached in a triangular or T-shaped fashion. If one does not know where the plane should be divided, this can be ascertained by expanding the lung and looking for the line of demarcation. However, we often find a cleft in the pulmonary parenchyma at the division of the superior from basilar segments. Once you have envisioned the plane to be divided, we approach parenchymal division from 2-3 directions, with the intersection in the middle.

Once the segment is free, it is placed in a bag and removed. At this time, if indicated, a lymph node dissection is performed. Intercostal blocks are placed, an air leak checked and a single 24-28 Fr chest tube is placed through the anterior inferior port. The most common segmentectomies performed by VATS include lingulectomy, lingular-sparing left upper lobectomy, superior segmentectomy and basilar segmentectomy (14). Although our focus is on superior and basilar segmentectomy, lung cancer appears most commonly in the upper lobes and so, equal proficiency at all forms of lobar and sublobar resection should be expected of thoracic surgical training at high volume centers (15).

Compared to wedge resection and lobectomy, segmentectomy is technically more challenging because of the individual dissection of bronchovascular structures by thoracoscopy (18). Bronchovascular anatomic variations are not uncommon and add to the complexity of the procedure. Variations of the lower lobe do not pose a significant challenge for accurate dissection as those in the upper lobe.
Discussion

As retrospective and prospective studies continue to shed light on the role of segmentectomy in the treatment of malignant and benign lesions, thoracic surgeons have continued to improve on the surgical technique so it can be safely performed according to specific patient needs.

This detailed description of superior and basilar segmentectomy can serve as a tool for thoracic surgeons at all levels of training. Although previously sublobar resections were associated with increased risk of locoregional recurrence in comparison to lobectomy, there is growing evidence that recurrence and overall survival in the setting of early-stage NSCLC (stage I and II) is superior to nonanatomic (wedge) resections and equivalent to lobectomy in the appropriately selected patient.7

In addition to the management of primary lung cancer, VATS segmentectomy is also an acceptable option for surgical resection of metastatic lesions, infection, carcinoid tumors, and benign nodules (eg, hamartomas). As the development of minimally invasive techniques continues to advance, teaching of complex procedures like superior and basilar segmentectomy to surgical trainees must also be reinforced.

Appendix A. Supplementary information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1053/j.op-techstcvs.2015.10.002.

References