HOW I TEACH A THORACOSCOPIC LOBECTOMY

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Since the initial introduction of lobectomy by video-assisted thoracoscopic surgery (VATS) in the 1990s, there have been many studies comparing its efficacy with that of the standard thoracotomy approach[1]. VATS lobectomy has demonstrated and recognized superiority over thoracotomy in several areas: (1) perioperative outcomes: fewer respiratory complications, blood transfusions, cardiac arrhythmias, and shorter length of stay[2,3]; (2) increased efficacy for higher risk populations (eg, elderly, poor pulmonary function)[4-6]; (3) improved cost effectiveness[7]; and (4) facilitated delivery of adjuvant chemotherapy for patients with N1–2 disease[8].

However, in 2010, less than 45% of anatomic pulmonary resections in The Society of Thoracic Surgeons general thoracic surgery database were performed through VATS[6]. More recently, approximately 60% of lobectomies performed for lung cancer have been done with VATS[9] - still much lower than the utilization of VATS in experienced programs. There are several potential reasons for the lag in widespread adoption of VATS lobectomy. The operation is technically challenging, requiring both cognitive and technical expertise[10]. A comprehensive knowledge of the three-dimensional anatomy and spatial relationships among the anatomic structures is mandatory, as are skills in minimally invasive surgery.

A learning curve is considered completed when the observed parameter (including operative time, conversion to open surgery, blood loss, hospital length of stay, and postoperative complications) reaches a steady state, and the results could be related to the limitations published in the medical literature. VATS requires specialized dexterity different from open surgery due to the transformation of a two-dimensional video image into a three-dimensional surgical field, the need for excellent eye-hand coordination, and the compensation of the reduced tactile feedback. Before starting a VATS lobectomy program, the surgeon should have in the surgical curriculum a considerable number of other VATS procedures. Through these minor procedures, the surgeon obtains the necessary skills (dissecting, stapling, and suturing), can then proceed to gain the skills for major VATS procedures. Naturally, the VATS lobectomy learning curve should growth from a more comfortable lobectomy to a challenging case. The inexpert surgeon should challenge first a VATS lobectomy of the right lower lobe, then of the left lower lobe, the right middle lobe, the right upper lobe, and lastly of the left upper lobe (Table 1).

Along with increasing experience, patient selection includes older, more advanced stage disease, and more compromised pulmonary function patients, without any concession in disease-free survival[11]. Also, the operative data collection in a database and the consultation with other skilled surgeons may help to abbreviate the learning curve[12]. On the other hand, teaching VATS lobectomies requires an adequate volume of patients because it is also well known that the surgical volume of VATS lobectomies significantly affects the quality of the procedure[13]. VATS procedures offer unique contests to teaching in the operating room because the supervisor has less opportunity to manipulate during the ongoing than the thoracotomy. During thoracotomy lobectomy, the role of operator and supervisor can exchange as the challenge of the case changes. The supervisor can even dissect with suction catheters without using the scissors. However, during VATS lobectomy the side where the operators stand, the specificity, the configuration, and placement of the instrumentation fix much more rigidly the role of the operator and supervisor during the procedure. If the supervisor would take over a significant portion of the operation, he will likely have to change positions with the operator[14].

Preparation for teaching VATS lobectomy begins with a needs assessment of the learner. It is important to have an understanding of the learner's baseline level of knowledge and experience with minimally invasive surgery in general, and with thoracoscopy in particular.

Before the case, the instructor should review the preoperative imaging and other relevant studies with the learner, with a focus on the lesion location and any anatomic variants or anomalies on the imaging studies. A discussion of the basic steps of the planned operation will also help to create a shared mental model of how the case will proceed. In addition, any potential pitfalls particular to the case, such as tumor involvement of the pulmonary artery (PA) or other critical structures that would prompt a change in the operative plan, should be discussed. Training videos are widely available, and may help to provide the learner with some baseline level of information

Figure 1

regarding the general conduct of the operation and techniques.

The instructor provides retraction of the lung to optimize exposure of the hilar structures. An active and progressive dialog between the instructor and the learner is essential and facilitates the learner's understanding of the operation. The discussion is tailored to the individual learner's level of experience and based on the needs assessment done before the case. For a novice learner, one should point out relevant anatomic structures and provide instruction regarding retraction and instrument use. In contrast, an experienced learner will require less instruction regarding basic technical concepts; the role of the instructor here is to provide guidance for finesse and cognitive points such as anticipating next steps or management of potential intraoperative complications, as well as to point out variations or aberrancies in anatomy that may still be not fully recognized by even experienced trainees (Figure 1 and 2).

Key technical points applicable to all VATS lobectomy cases include the following[15]:

1. The learner must understand and memorize the pathway of instrument ingress for the current case. The learner should be able to introduce instruments into the pleural space without injuring the chest wall or hilum by recognizing the relationship of the relative positions of hilar structures to the incision.

2. The first goal of the dissection should be recognized to be "lengthening the hilum'" for both upper and lower lobectomy; division of the posterior pleural reflection greatly improves the ability to perform safe dissection of the arterial branches later in the case.

3. There should be no tension on the PA; dissect structures away from PA and its branches. Complications can be avoided by carefully avoiding excessive tension on the PA during both retraction and dissection. The pulmonary vein and bronchus will tolerate some degree of tension, and therefore developing tissue planes between these structures and the PA should focus on dissecting them away from the PA to avoid injury.

4. Hilar lymph nodes should be dissected away and removed to reveal the hilar anatomy and facilitate dissection of relevant structures. In more challenging cases, we encourage removal of all visible lymph nodes during dissection, which facilitates arterial and bronchial dissection later in the case.

Technical performance during training could be determined by repeated examinations, leading to longitudinal analysis development and developmental feedback. The developmental feedback would permit helpful criticism regarding performance, allowing the highlight of specific deficiencies and the correction with beset training and could be used to determine the progress or the need for repetition of a training task [16]. The skills in a new technique should not be built exclusively on the numbers of procedures but the assessment of skills and outcomes. The transparent educational involvement should include the verification of the acquisition of knowledge, skill, safety, and the monitor of the outcomes[17].

Patient safety must be, and remain, the first priority throughout the operation. It should be obvious that errors are best avoided, rather than managed. Active dialog between instructor and learner, to continue the idea of a shared mental model, will help to minimize errors. When they do occur, cognitive errors are easier to correct than technical errors. When a technical error is made, the instructor may need to temporarily take over the case to correct the situation[18].

CONCLUSION

As with all operative techniques, proficiency in performing VATS lobectomy is achieved with progressive and consistent experience. As the learner progresses from novice to experienced, he or she gains autonomy and require less instruction and assistance. It is critical that the instructor accurately perceives the learner's level and needs, to reduce frustration and optimize the learning experience for both parties. Consistent exposure to VATS lobectomy at a high-volume center enables the learner to build on each experience and to progress most efficiently from novice to proficient.

Figure 2

Table 1 **(adapted from [19] and [20])**

Right upper lobectomy	Left upper lobectomy
1. The surgical steps are similar to left upper lobectomy: anterior and apical segmental trunk, upper vein, posterior segmental artery, upper bronchus, fissure.	1. The operative sequence for left upper lobectomies is similar to conventional VATS. However, first divide the upper anterior and apical segmental trunk in order to facilitate the insertion of the endostaplers in the upper lobe vein.
2. Sometimes it is helpful to partially divide the minor fissure as the first step in order to get a better angle for the insertion the staplers to the upper vein. This maneuver will provide us with a much better field of vision to dissect and transect the bronchus or the ascending arteries.	2. Once this arterial branch is stapled, the vein is easily exposed. The use of curved-tip stapler technology facilitates improved placement around superior pulmonary vein and bronchus through a single incision.
3. The last step would be to complete the fissure. After transecting the vein, artery and bronchus and after identifying the artery for the middle lobe, we can continue to divide the fissure by placing the stapler over the interlobar artery, pulling the parenchyma anteriorly making sure that the middle lobe artery is left out to the left side of the stapler.	3. The management of bronchus during left upper lobectomies is more difficult because care must to be taken with lingular artery which lies usually behind the bronchus. The first option consists of exposing the lingular artery and subsequently dividing it in the fissure. At this point, the insertion of an endostapler for the bronchus is easy.
Middle lobectomy	
1. We recommend to perform the middle lobectomy from caudal to cranial: anterior portion of major fissure, vein, bronchus, artery, anterior portion of minor fissure and finally the posterior portion of fissure.	
2. Once the vein is divided, the middle lobe bronchus is exposed, dissected and stapled. A ring forceps is then placed to exert traction onto the middle lobe, thereby exposing the middle lobe artery, which is then divided.	
3. Finally, the fissures are stapled.	
Right lower lobectomies	**Left lower lobectomies**
1. For lobectomies when performed along a caudo-cranial axis, care must be taken to identify and avoid the damage of the bronchus or artery of the middle lobe.	1. The lobectomy may be technically different depending on whether the fissure is complete or not. If fissure is complete try to dissect and staple the artery in the fissure. Sometimes, it is easier to individually divide the arterial branches of the superior and basilar segments.
2. Once the inferior pulmonary vein has been stapled, the lower lobe bronchus is exposed, dissected and divided from its inferior aspect to its bifurcation with the middle lobe bronchus.	2. In the presence on an incomplete fissure or no visible artery, the lobectomy must be performed from caudal to cranial leaving the fissure stapling as the last step (fissureless technique). Once the lobe is retracted cranially, the sequence of the dissection should be as follows: inferior pulmonary ligament; inferior vein; inferior bronchus. Subsequently, a plane is created between the bronchus and the artery; the artery is taken thus leaving the fissure to be developed last.
3. Remove the interbronchial lymph nodes to better define the anatomy.	
4. Once identified, the segmental arterial branches to the lower lobe (basilar artery and superior segmental artery) are divided leaving the fissure to be finally stapled (Video 7).	

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