Thoracoscopic lymphadenectomy via uniportal approach

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Abstract: Performing a radical lymphadenectomy is an obligation for a complete resection in non-small cell lung cancer. Mediastinal lymphadenectomy is indicated whenever a diagnosis of lymphadenopathy is not possible via imaging techniques. With the uprising use of uniportal video-assisted thoracoscopy and the accumulating literature of its safety and efficacy compared to multiportal approach, thoracoscopic lymphadenectomy via uniportal approach is a common terminology to come across. The use of uniportal video-assisted thoracoscopy lymphadenectomy offers a lower complication rate, postoperative paresthesia, and pain when compared to the multiportal approach. With a reported higher tolerability, efficiency, safety, and better cosmetic outcome; it is more appealing to the patients. Though it is becoming easier to perform with experience, it is still a complicated procedure with many challenges. These challenges can be related to implementing the technique itself, or due to its linkage to the development of the instruments industry and the overall high cost of the procedure. In this review, we walk you through the history of the approach from the idea to todays' form of video-assisted thoracoscopy, mediastinal lymphadenectomy via uniportal video-assisted thoracoscopy indications, contraindications, and outcomes; an extensive explanation of the lymph node dissection technique with specific considerations for each lymph node station. The article is supplemented with an anatomical overview of the mediastinal lymph nodes; supported by videos of the technique for a better visual review and learning experience, ending with extra challenges faced in implementing the technique in developing countries.

Keywords: Lymphadenectomy; lymph node dissection; uniportal VATS; uniportal VATS technique; single port

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Introduction

The use of single-port video-assisted thoracoscopic (uniportal VATS) approach to perform lymphadenectomy has become the new trend in the thoracic surgery community (1). This is expected since it is the least invasive approach compared to the multi-portal video-assisted thoracoscopic surgery (VATS), less painful and traumatic to the patient with a shorter hospital stay and a lower rate of complications. From a patient perspective, uniportal VATS is associated with a better cosmesis, which increases patients satisfaction. This, along with its previously mentioned advantages, results in more patients being keen on it (2,3).

Even though the learning curve for this approach is steep, the advantages and improved outcomes are tempting. Therefore, we find more surgical teams from both new and

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old generations are leaning toward learning this technique with the intent of mastering the specific surgical steps required to perform it successfully (2,3).

The early use of the uniportal technique was for simple non-anatomical pulmonary resections and biopsies, mediastinal nodal diagnosis, and staging (4-6). However, this technique has grown in the last few years, which allows its use in more complicated thoracic surgeries as pulmonary sleeve resections (7). These rapid developments and improvements in the technique were made possible by the information shared through the internet, live surgery events, and experimental courses; along with the growing experience of thoracic surgeons. However, with this height of implementation, thoracic surgeons are faced with more challenges and technical difficulties in operating more complicated cases using the uniportal VATS approach (8,9).

Overall, the technique is considered a feasible alternative to the multi-portal approach from a surgeon and patient point of view.

Methodology

A search was completed in MEDLINE and SCOPUS databases on the 6th of September using the following keywords: thoracoscopic lymphadenectomy, VATS, uniportal approach, thoracoscopic lymph node dissection, single-incision, lung cancer, video-assisted thoracoscopic surgery, and other terms related to the main theme of the review.

The literature on uniportal VATS lymphadenectomy was limited. Therefore, our inclusion criteria consisted of original articles, review articles, and meta-analyses on uniportal VATS lymphadenectomy or comparing uniportal VATS lymphadenectomy to other thoracic lymphadenectomy approaches. While the exclusion criteria consisted of articles not discussing lymphadenectomy, articles with weak evidence, case reports, and articles not written in English.

The History behind uniportal VATS

The increased popularity and variety of adopting the uniportal technique in recent years might lead to the misguided thought of it being a recent invention (10). However, its history dates to when Georg Kelling, a German internist, performed the first laparoscopic surgery on a dog in 1901. Later in 1910, Hans C. Jacobaeus, a Swedish internist unaware of Kellings' work, considered the father of thoracoscopy, reported his experience performing the first laparoscopic surgery on a human and published it under the title "The Possibilities for Performing Cystoscopy in Examinations of Serous Cavities". He continued to experiment more to define the difficulties and limitations to promote it in the medical community better (11,12). He used a cystoscope to inspect the pleural cavity in two patients with tuberculous pleural effusion. Two years later, he published describing thoracoscopy in full detail. The technique went global under the name "jacobaeus operation" (3).

Furthermore, two methods were used, a single-entry site and the two entry site (13,14).

The development of VATS, video-assisted thoracoscopic surgery, was pushed by the advances in minimally invasive abdominal surgery. Thoracic surgeons were excited and eager to experience, especially after the improvement of instruments utilized and the advantages of this approach compared with the open approach they were used to perform. A camera was attached to an eyepiece, and then there, the VATS was invented (14). The final version of the technique surgeons use nowadays was first described in 2004 by Gaetano Rocco in his article " How to do it: Uniportal VATS wedge pulmonary resections." He described its use for diagnosing interstitial lung disease and treatment for primary spontaneous pneumothorax (6).

Lymphadenectomy: indication, contraindications, and outcomes

Lymphadenectomy is indicated for diagnosis when other non-invasive methods are non-available or fail lung cancer staging or diagnosis of lymphadenopathy (15).

Uniportal VATS can be used for mediastinal lymph nodes resection or sampling, whether for diagnostic or staging purposes efficiently. This can be done when the lymph node stations are inaccessible via cervical mediastinoscopy or anterior mediastinotomy (paraesophageal lymph nodes) or when the traditional techniques are not safe (after a complicated neck surgery or a stereotomy) (4). While systematic lymph node dissection is crucial in lung cancer staging and can safely be performed via uniportal VATS (16).

The traditional contraindications for uniportal VATS technique are related to performing lobectomies, which include: dense pleural adhesions, incompleteness of interlobar fissure, previous chemo- or/and radiotherapy, perivascular or/and peribronchial fibrosis. Some are related to the tumor characteristics, including tumors larger than

5 cm, chest wall involvement, centrally located tumors. In contrast, others are patient-related, like severe comorbidity, advanced age, severe chronic obstructive pulmonary disease (COPD), and emphysema.

Vadim G. Pischik reevaluated these contraindications, and most were proven operable. Thus, his work further extended uniportal VATS indications to cover most of what was previously believed inoperable (17).

Currently, the absolute contraindications for lymphadenectomy via the uniportal VATS approach are related to the surgeons' discomfort and tumors associated with mediastinal invasion, and huge tumors are not possible to remove without rib spreading (18).

Uniportal VATS in comparison to other approaches

With the advancement of thoracoscopic instruments and endoscopic cameras, more thoracic surgeons are choosing to learn the VATS techniques over the open approach with the preference of the uniportal over the multi-portal methods (5,19).

This can be understood if we analyze its advantages and disadvantages compared with other approaches. The thoracoscopic approach showed a higher satisfaction rate among patients, being more tolerable, efficient, and safer (5,20). Many studies showed that the minimally invasive approach resulted in less hospital stay, less pain postoperatively, better cosmetic outcome, and less trauma to the lung parenchyma and adjacent tissue. Moreover, it is becoming easier to perform and more feasible for surgeons with proper experience (19,21).

Furthermore, the uniportal approach is more favorable than the bi- or tri-portal approach since it is associated with a lower complication rate, postoperative paresthesia, and pain when compared to the conventional multi portal approach (5,22-24) Although it's more costly, this can be balanced out with less hospital stay (25).

Regarding lymphadenectomy, the mean number of lymph nodes dissected with the uniportal was 14.5±7, while 11.9±6.7 was the mean using the multi portal approach (8). Overall, the VATS uniportal approach is better than the open approach (15). Regarding the indications, complications, safety, and operative time, there was no difference between the uniportal and the multi-portal approaches (26-30). With the same results are comparable to open thoracotomy (31).

While still being able to sample and radically remove mediastinal lymph nodes of any size (4). Moreover, some authors suggest that uniportal VATS represents the best view for lymphadenectomy (32).

As much as surgeons appreciate the advantages, there are areas of concern with the uniportal approach. Operating through one port comes with operative challenges. There is more difficulty in moving the instruments for better visualization, loss of triangulation, lack of exposure, and with less experienced hands, there might be a sword fighting of the camera or the telescope with the instruments (33).

Mediastinal lymph node anatomy

The techniques used for lymphadenectomy are specified based on the anatomical position of the lymph nodes. Therefore a brief description of the lymph nodes anatomy is provided in this section.

The maze of the lymphatic vessels network in the human body makes it a complicated map to describe (34). There are many lymph nodes mapping classification systems that are disease-specific. Here, we are explaining the most used mapping classification, which is based on the lung cancer staging guidelines (35). The IASLC has proposed to divide lymph nodes into 14 stations in seven lymph node zones as displayed in *Table 1* (1,36).

Lymphadenectomy technique via uniportal VATS

The general aspects of performing uniportal VATS are almost the same for every operation; though each surgery has its special tactics and tricks.

When performing a uniportal VATS, a 3–5 cm incision is made in the anterior fifth intercostal space. The thoracoscope is inserted in the posterior part of the incision as the instruments are inserted in the anterior part of the incision. A 30-degree thoracoscope via the single incision allows for direct visualization of the tissue being handled.

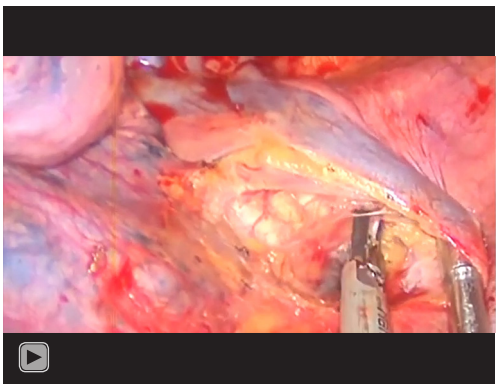
To obtain the same thoracoscopic view, both the surgeon and the assistant are positioned in front of the patient. The patient is classically placed in a lateral decubitus position but is changed depending on the type of case (1).

Recently, many surgeons started to adopt the "Shanghai pulmonary hospital-style" where the leading surgeon stands in front of the patient while the first assistant stands on the opposite side. In the beginning, it may be difficult for a camera operator to learn this position, but might be preferred over time, as it gives both the surgeon and his/her assistant their own space and greater freedom of movement (37).

Table 1 Mediastinal lymph node zones and stations

The zone	Stations
Supraclavicular zone	One station that is the most cranial of all mediastinal nodes, divided into right and left by the midline of the trachea
Upper zone (superior mediastinal)	Contains stations 2, 3, and 4. Station 2 is called the upper paratracheal and divided into right and left by the lateral wall of the trachea. Station 3 is divided into prevascular and retrotracheal. Station 4 (lower paratracheal), is divided into right and left by the tracheal left lateral wall
Aortopulmonary zone	Station 5 LNs, also known as subaortic, and the para-aortic LNs (station 6)
Subcarinal	One station only (station 7)
Lower zone (the inferior mediastinal)	Contains stations 8 and 9, known as paraesophageal and pulmonary ligament respectively
Hilar zone	Station 10 is divided into right and left
Interlobar and peripheral zone	Station 11 (interlobar), and stations 12–14 (peripheral)

LNs, lymph nodes.



Video 1 Uniportal VATS dissection of para-tracheal mediastinal lymph nodes (station 2 and station 4). VATS, video-assisted thoracoscopic surgery.

For lymphadenectomy, the process is much alike but with few alterations. As usual, the camera is placed in the incision's posterior part while the instruments are placed anteriorly. The patient is moved to an anti-Trendelenburg position to assist in paratracheal lymph node group dissection, while the Trendelenburg position with anterior table rotation is used for the subcranial group dissection (18).

Alongside positioning, other factors that are of high importance are experience and surgical equipment, among others.

We previously mentioned the use of the 30-degree thoracoscope, other of-value surgical materials include:

(I) High definition monitor screen (preferably 4K);

(II) Short and double-jointed curved ring forceps instruments;

(III) Energy devices and a Sponge stick.

The specific use of the long and curved equipment rather than the conventional equipment aids in the dissection and pulling of the lymph nodes, while experience, on the other hand, correlates with a higher number of lymph nodes dissected and overall improvement in technique utilization (32).

There are specific technique considerations for each station of lymph nodes based on the mediastinal space; as follows.

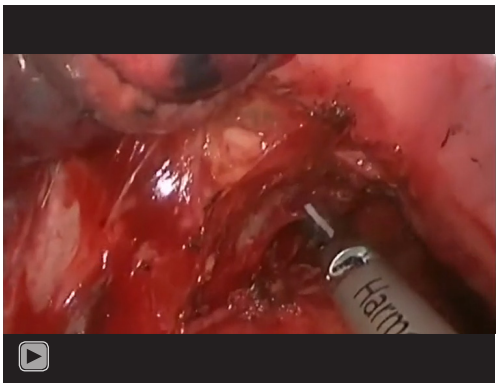
Right paratracheal space

All the mediastinal nodes and fat between the trachea and cava vein are removed. Some authors recommend opening the pleural space (1,11), while others find it unnecessary (32). The dissection is done going under the azygos vein. The result is a tunnel view (*Video 1*).

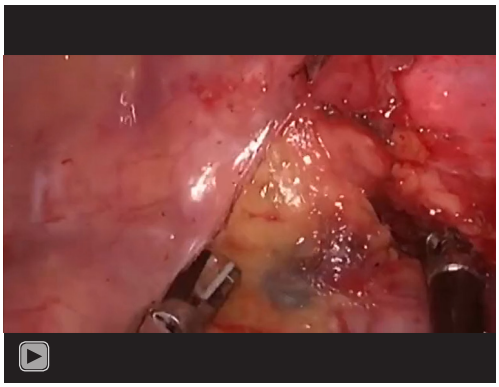
Subcarinal space

The most challenging lymph nodes to dissect are the left subcarinal station because they are located deep. The descending aorta retracted on the left side, and the esophagus on the right side, thus allowing for a widened view of the subcarinal space. The retraction of the lung is done using a sponge stick or another instrument like curved suction or endo peanuts. The dissection has to be done carefully and delicately (*Video 2*).

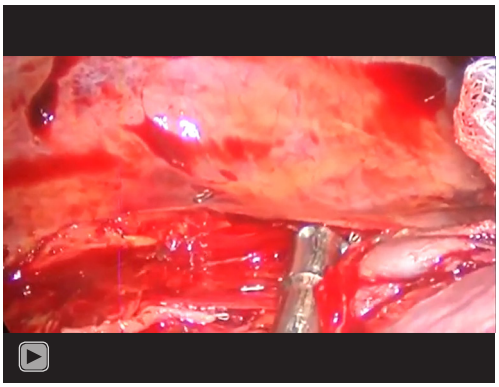
For right subcarinal lymphadenectomy, the separation of the esophagus and the intermediate bronchus facilitates the



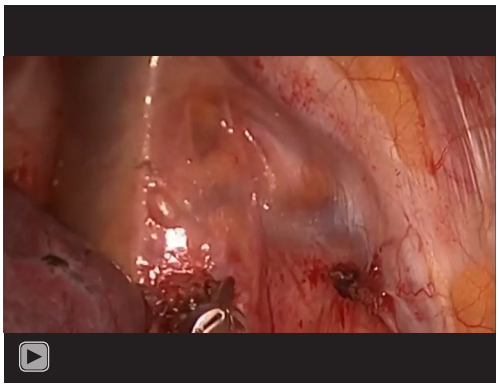
Video 2 Uniportal VATS dissection of subcarinal mediastinal lymph nodes (station 7) from the left side. VATS, video-assisted thoracoscopic surgery.



Video 4 Uniportal VATS dissection of Aorto-Pulmonary window station mediastinal lymph nodes (station 5). VATS, video-assisted thoracoscopic surgery.



Video 3 Uniportal VATS dissection of subcarinal mediastinal lymph nodes (station 7) from the right side. VATS, video-assisted thoracoscopic surgery.



Video 5 Advanced instrumentation for lymphadenectomy via uniportal VATS technique "non-grasping method". VATS, video-assisted thoracoscopic surgery.

procedure (*Video 3*).

Aortopulmonary window space:

This procedure removes lymph nodes at the aortic arch and the left main pulmonary artery.

The phrenic nerve is retracted to allow for better exposure of the prevascular area. While the recurrent laryngeal nerve must be protected to avoid vocal cord paralysis (15,18,32) (*Video 4*).

With the surgeon gaining experience, he can begin dissecting the lymph nodes using the bimanual advanced instrumentation method or the so-called "non-grasping technique" using the suction and the energy device without grasping the sample to afford an ideal sample pathological analysis (38) (*Video 5*).

Mediastinal lymphadenectomy is usually performed after the surgeons are done with lung resection. However, it can be performed before lung removal as this allows the surgeons to work in a drier field (15).

Extra challenges in developing countries

Developing countries face specific challenges when it comes to the use of uniportal VATS. Its high cost represents huge concern when it comes to the individual cost of the consumables and the overall price. Studies showed that this issue can be a huge hindrance to applying VATS. The true role of this technique has to be evaluated in a country with a low socioeconomic state. The high cost of the consumables

put questions on whether it is a cost-effective technique. It is essential if VATS is not going to be a privilege only to the few who can afford it (39,40).

Another challenge devastating the implementation of uniportal VATS in developing countries is the limited number of thoracic surgeons. The main reason behind this restriction is how the uniportal VATS technique is learned. With no detailed standardized description of the steps, the technique, or the tricks to overcome the operative problems; being taught exclusively by experienced surgeons (41). Moreover, the technological development and implementation are linked with the thoracoscopic instruments' development, availability, and cost. Thus even if doctors train in developed countries; the lack of types of equipment in their home countries remains an issue.

The problem extended to include insufficient human capacity, especially those who are competent for such procedures (42). All this puts an enormous burden on the use of VATS in developing countries.

Conclusions

Performing a complete lymph node dissection using the uniportal VATS approach was once believed to be impossible, but with more experience and trial, it has become a difficult procedure. Nowadays, performing lymphadenectomy whether with complete lymph node dissection or not yields the same results as conventional VATS with better outcomes.

We highly emphasize the steep learning curve of the procedure, the experience needed by the surgeon to be able to yield the expected outcomes, and the equipment needed.

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