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Minimally Invasive Thoracic Surgery - Video Assisted Thoracic Surgery: Technique and Indications

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Rezumat

Chirurgie toracică miniminvazivă - chirurgia toracică video-asistată: tehnică și indicații

Chirurgia toracică video-asistată CTVA (VATS) este, la ora actuală, practicată în întreaga lume pentru aproape toate patologiile tratabile prin chirurgie toracică deschisă (toracotomie). Ca parte din chirurgia toracică miniminvazivă (MITS), CTVA sau VATS oferă atât pacienților cât şi medicilor rezultate excelente şi satisfacții profesionale pe măsură. Acest articol prezintă VATS sub aspectele sale de clasificare, indicații şi contraindicații, instrumente, incizii şi abord, incidente şi conversie, curbă de învățare şi training. Ne dorim ca aceste informații să fie de folos tuturor colegilor, rezidenți sau medici cu experiență chirurgicală toracică, pentru a putea începe şi continua în siguranță VATS ca standard chirurgical toracic.

Cuvinte cheie: chirurgie toracică video-asistată (CTVA-VATS), chirurgie toracică minim-invazivă (MITS), tehnică chirurgicală toracică, cancer pulmonary, metodă de învățare CTVA-VATS, training în CTVA-VATS

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Abstract
Video-Assisted Thoracic Surgery (VATS) is already practised worldwide, in almost every condition addressed by open thoracic surgery. As part of minimally invasive thoracic surgery (MITS), VATS offers to patients and to healthcare providers excellent results and great satisfactions. Learning and performing VATS use different pathways in trainees and in experienced surgeons. This article presents VATS in its essence: classification, indications, contraindications, instruments and tools, incisions and access, troubleshooting, learning curve and training. We wish that the information helps our colleagues, both trainees and experienced thoracic surgeons, to start and continue performing VATS as standard care in thoracic surgery.

Key words: Video-Assisted Thoracic Surgery (VATS), minimally invasive thoracic surgery (MITS), thoracic surgery technique, lung cancer, learning VATS, training in VATS

Introduction

Minimally invasive thoracic surgery (MITS) comprises of a broad range of procedures done under video-assisted view and using small incisions that mind the tissues or the intercostal space, and addresses most thoracic pathologies.

Although along the time different techniques have undergone significant improvements and changes, mostly due to the massive boom of technology and digital tools, MITS prerogatives stay the same and entitle: minimal incision size, no rib spreading, oncological limit resections and fast postoperative recovery. The great advantages of the minimally invasive methods add-on also: a lesser need for pain medication postoperatively, possibility for fast-track to oncological treatment, a shorten hospital stay, resume of daily activities and faster mobilization of the patient after surgery, undebatable improved quality of life (QOL) and also a more esthetical pleasing outcome of the surgical wound. Current established MITS procedures are (1,2):

- bronchoscopic procedures – endobronchial tumor ablation by LASER ND-YAG, cryoablation, cauterization,
- mediastinoscopy, VAMLA (Video-Assisted Mediastinoscopic Lymphadenectomy),
- esophageal and peroral procedures,
- thoracoscopy video-assisted thoracic surgery (VATS) and its variants,
- robotic assisted thoracic surgery (RATS).

Video Assited Thoracic Surgery

The great progress of technology, the advances in anesthesia procedures, and ambition and tireless work of thoracic surgeons from all around the world to innovate, opened the road to a new era - the Video Assisted Thoracic Surgery (VATS). Today VATS can mirror almost all type of thoracic surgical procedures done by open (classic) surgery, given proper instrument resources and an experienced team (3,4). This type of approach comprises of 2-3 intercostal ports or one single incision – a 2-3 cm mini-thoracotomy that will serve as access for all the instruments and for the thoracoscopic camera; variants are subxiphoid and subcostal approach (5) and combination of intercostal approach and TEMLA (6). VATS instruments mimic classic thoracic surgery instruments but are specially designed to fit thru small incisions and to articulate proximal or distal depending on the need. They often serve multiple purposes at the same time in order to save up space and allow for a fine feedback grasp. *Fig. 1* presents one possibility of operating room setting, including a set of VATS instruments – details cannot be offered

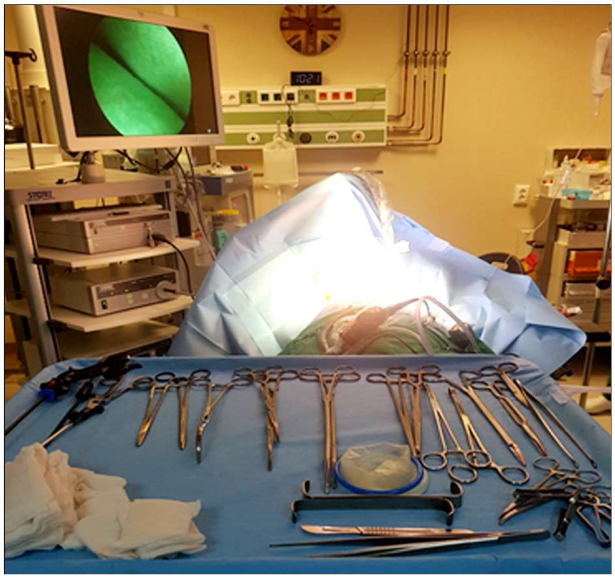

Figure 1. Setting of the operating room for right VATS approach with one monitor; whenever possible, 2-monitor set is a better option

because of commercial reasons. As mentioned, one of the key elements of VATS is no rib spreading so to protect the intercostal space special wound protectors (latex, gel) are used or trocars (*Fig. 2*).

Clasification VATS

- BY TYPE OF ACCESS (number of ports/ incisions) – see below, in "Incision and access";
- BY TYPE OF ANESTHESIA:
  - selective intubation,
  - non-intubated (7).

VATS can be performed by multiple ports or single incision located in different areas as summarized in *Table 1*. Regardless of the type, all VATS procedures have the same characteristics: minimal incisions, no rib-spreading and video assistance through the operation.

Table 1. Type of VATS procedures by incisions

MULTIPORT-VATS	Conventional 2-3 intercostal ports ± 1 mini-thoracotomy
UNIPORTAL-VATS	Single incision - 1 mini-thoracotomy
SUBXIFOID VATS	3 cm incision below the xiphoidal process
TRANSCERVICAL VATS (5)	6 cm cervical incision

Figure 2. Wound protectors
Finochietto rib spreader - used for classic open thoracic surgery through thoracotomy. Metal thoracoscopic port with inserter - used for insertion of the thoracoscopic camera or a thoracoscopic surgical instrument. Usually, thoracoscopy is performed without CO2 insufflation.
Wound protector, soft – no rib spreading.

Indications VATS

Such as in open surgery, VATS procedures serve for diagnostic purposes or therapeutic and oncological radical surgeries for lung cancer and other thoracic malignancies. As we established earlier, VATS can offer almost all type of thoracic surgical procedures done by open (classic) surgery and is not the right place and interest to exhaustively present the indications for thoracic surgery; for educations purposes, we can summarize VATS indications as follows [adapted after ESTS Textbook (8)]:

Indications by objectives:

- diagnostic/therapeutic,
- radical surgery/paleative.

Indications by organ:

1. lung:
   - primary tumors – lung cancer, benign tumors,
   - secondary tumors - metastasis,
   - congenital,
   - inflamatory,
   - infectious.
2. mediastinum:
   - tymic tumors/pathology,
   - MLND = mediastinal lymph node dissection,
   - neurogenic tumors.
3. pleura
   - mesothelioma,
   - metasthasis,

- tumors,
- effusions.

4. diaphragm
   - hernias,
   - diaphragmatic relaxation.
5. esophagus
   - tumors,
   - functional esophageal diseases.
6. chest wall
   - congenital,
   - tumors,
   - trauma.
7. Others
   - sympathetic chain - hyperhydrosis,
   - splahnic nerves - pain management,
   - thoracic duct.

Out of all the thoracic procedures that can be addressed by VATS, a special interest and main focus is that of anatomical lung resections and mediastinal lymph node dissection, granted also due to great development of endoscopic stapling devices that evolved along with minimally invasive techniques and surgeon's needs (5,9).

A great rise is also noted in regards to segmentectomies, sub-segmentectomies or combined sub-segmentectomies (10). Here we will summarize the main VATS anatomical lung resections:

- lobectomies:
  1. right upper lobectomy (RUL);
  2. midlle lobectomy (ML);
  3. right lower lobectomy (RLL);
  4. left upper lobectomy (LUL);
  5. left lower lobectomy (LLL);
- upper bilobectomy;
- lower bilobectomy;
- left/right pneumonectomy;
- sleeve resections – bronchial, arterial;
- segmentectomies:
  - for upper lobes:
    1. right apical segmentectomy (S1);
    2. right dorsal segmentectomy (S2) (only for the right lung. For left lung S1+2);
    3. ventral segmentectomy (S3).
  - for lower lobes:
    1. Superior segmentectomy (S6);
    2. Ventral segmentectomy (S8);
    3. Lateral segmentectomy (S9);
    4. Dorsal segmentectomy (S10).

Contraindications VATS

Although VATS procedures can be applied in virtually any thoracic pathology, some particularities even though relative, might contraindicate the procedure in specific cases. These are correlated also with the contraindications of the specific case unrelated to the surgical approach:

- impossible single lung ventilation;
- multiple strong adhesions;
- tumor dimensions.

In time, instruments specifically designed for VATS and the increase in skills and experience of both the surgical and anesthesiology teams made the list of contraindications lesser and the one for indications wider.

Instruments and Tools

A safe and feasible VATS approach is always related to both skills and instruments. All members of the operating room should know the circuit of the tools (monitor placement, pedals) and how to troubleshoot in case of necessity.

Room set-up

- patient positioning on the table - lateral decubitus with the arm secured on the arm rest (*Fig. 2*);
- main tools and pedals regarding the lead surgeon.

Monitor Placement

RUL, ML – posterior top.
RLL – posterior bottom.
LUL – top (as cranial as possible, minding anesthesia access).
LLL – posterior top.

Table set-up

In the beginning for safety reasons, it is advisable to set two tables ready: one with main VATS instruments and one with conventional instruments for open surgery (in case of emergency conversion).

Instruments

- Long, straight and curved instruments, specifically designed for VATS (*Fig. 1*; details cannot be offered because of commercial reasons) (11).
- Sponge stick for emergencies (compression in case of vascular injury).
- Staplers, energy devices.

Camera

- Recommended, at least for beginning: 10 mm 30°.
- Golden rule: always try to keep the action in the middle of the image.
- Camera should be placed in the posterior corner of the wound and instruments in the front – for uniportal anterior access (*Fig. 3*).

Incisions and access (11)

3-PORT VATS

- Before development of articulating staplers – triangulation principle:
  - o posterior port (just anterior to scapular tip),
  - o anterior port (7^{th}-8^{th} ic space in the midaxillary line, for camera) and
  - o utility port of 3-6 cm in 4^{th}-5^{th} ic space.
- Articulating staplers available:
  - o camera port more anteriorly,
  - o posterior port lower (stapler access),
  - o camera holder next to main surgeon,

allowing for better coordination surgeon-assistant, less pain for the patient (ic spaces larger more anteriorly), more like open access because the axis of operation changed from hip-head to umbilicus-scapula, direct access on hilum, didactic benefits.

2-PORT VATS

- camera port in 7^{th}-8^{th} ic space in the midaxillary line,
- utility incision anterior in the 5^{th} ic space, frequent changing camera position for allowing retraction, dissection and stapling ("sharing" the utility incision); developing fissure-last technique.

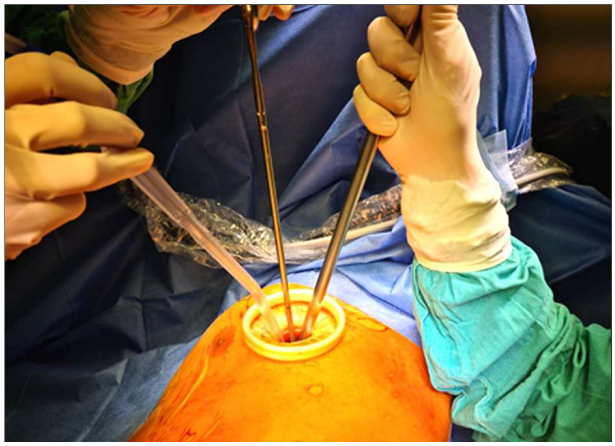

Figure 3. Camera and instruments placement in uniportal VATS: camera at the posterior part, and the instruments (holding and working instruments) in the middle and anterior; when used, stapler is inserted in the anterior part

UNIPORTAL-VATS

- 2-4 cm anterior incision 4^{th} or 5^{th} ic (intercostal) space (5);
- variant: the modified uniportal VATS Duke approach: 5 mm adjacent incision in the same ic space – protects the camera, separates the chest tube from the wound (12).
- a natural progression of MITS; access and image - as in open surgery (*Fig. 4*).

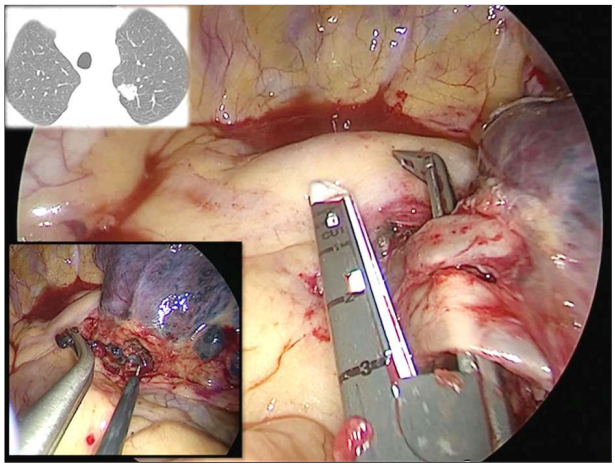

Figure 4. Intraoperative uniportal VATS aspect: radical left upper tri-segmentectomy (culmenectomy) for lung cancer – 2 pulmonary arterial branches dissected and prepared for stapling (main picture); adenocarcinoma presenting as ground-glass opacity GGO nodule (left upper insert); hilar and intrapulmonary lymphadenectomy – lymph node chain dissected with electrocautery (left lower insert)

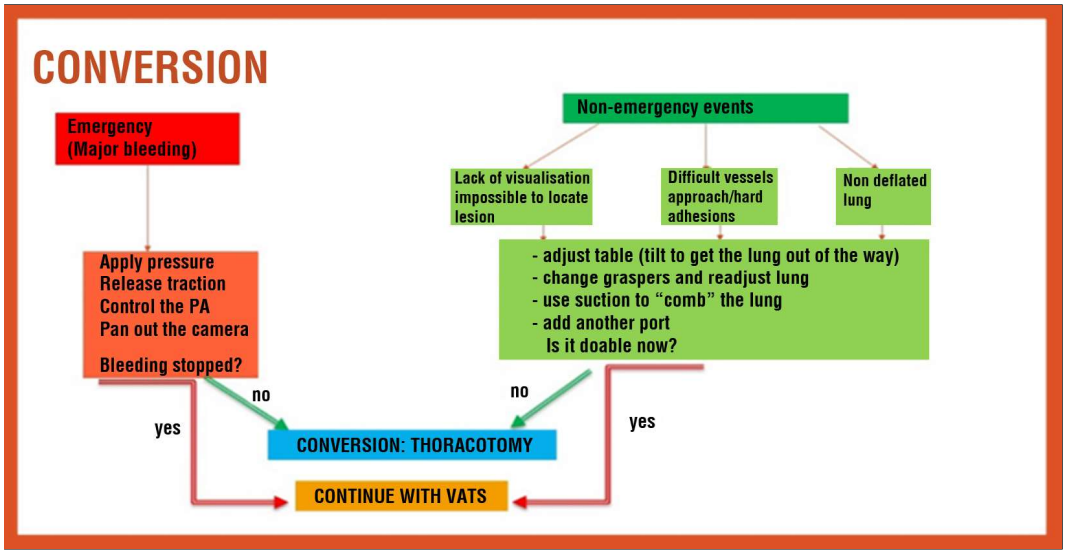

Figure 5. Conversion from VATS to open surgery (thoracotomy).

Troubleshooting

Conversion to thoracotomy

As part of the learning curve, conversion makes for a big number of cases particularly in the beginning. Although emergency bleeding by damaging a vessel can occur imposing conversion to open surgery, most commonly conversion is due to other factors that affect the confidence of the surgical team in the method as we exemplified in *Fig. 5*. "Conversion to open when performed in an intentional, controlled manner should not be seen as a sign of failure." (11).

- *bleeding from major vessel*

Bleeding control is obtained by direct compression with suction, with the lung parenchyma or with a sponge stick/ gauze; if needed, vascular suture (angiorhaphy) is performed. Thoracotomy is made if VATS maneuvers are not successful or if the team is more confident in open thoracic surgery (13).

- *oncological reasons*

In oncological thoracic surgery, failure to obtain R0 resection by VATS (regarding tumor extension or lymph node dissection) is a strong indication to convert to open thoracic surgery – oncological resection and safety are supreme goals (14-16).

Most common reasons for conversion and how to approach them:

- *hard to locate lesion*

There are different methods to mark the lesion before surgery (e.g.CT guided hook-wire or methylene blue marking - *Fig. 6*) or during surgery. Most commonly used methods depending on the resources available are:

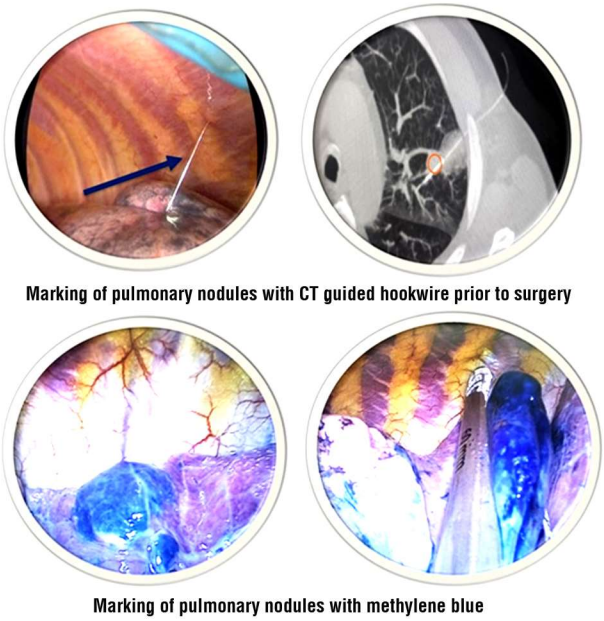

Figure 6. Marked pulmonary nodules for identification and resection

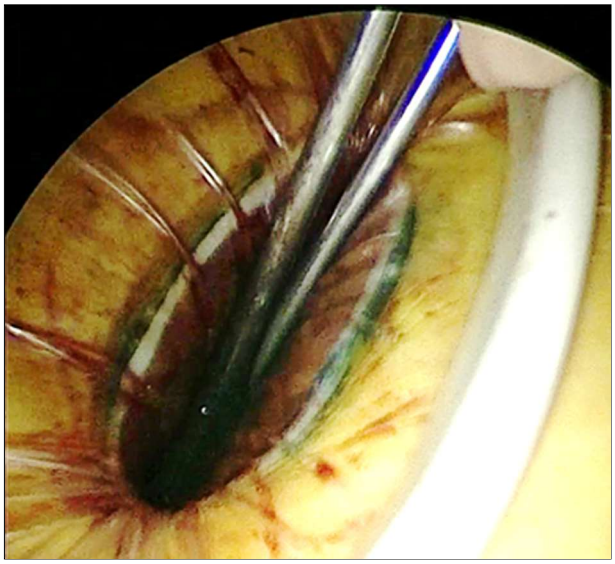

Figure 7. Narrow intercostal space with wound protector – through this incision an uniportal VATS middle lobectomy was performed

- Liquid agents (e.g., methylene blue);
- CT guided hook wire;
- Radiolabeled aggregates;
- Microcoils;
- Intraoperative ultrasonography;
- Navigational bronchoscopy.

These methods allow for safely locating the lesion and removal of as much as little healthy tissue as possible (respecting oncological margin of resection).

- *Narrow intercostal space (Fig. 7)*

- removing the wound protector to fit instruments;
- add another port if necessary (e.g.for inserting the stapler, or to adjust the angle to approach a vessel);
- costal section and suture of the rib at the end (uniportal VATS - for extracting large specimen);
- separate (subxiphoid or subcostal) extraction incision (for extracting large specimen and for avoiding rib trauma).

- *stapler related*

Staplers can misfire or jam. It is most common due to a malfunction of the handler and less common of the manufacturer. Depending on the issue: It is recommended to open and close it again, if possible, to remove it slowly, and apply another under it or apply clips if not fired completely at the edge; if blocked, a safe conversion may be necessary for vascular control.

- *small incision*

In case of insufficient space for instruments or lack of a proper angle for the stapler, another port can be added at any point of the surgery (*Fig. 8*). During uniportal VATS, the

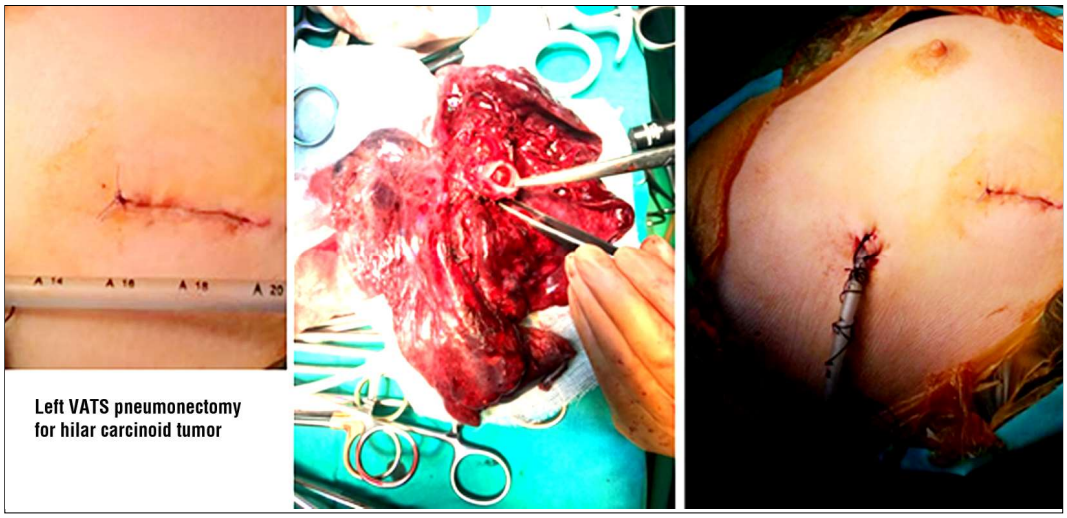

Figure 8. Two incisions for VATS left pneumonectomy - 4 cm incision used for uniportal initial instrumentation and final extraction of the entire lung, second 1cm port used for optimal stapler positioning and chest drainage at the end of the surgery

Figure 9. Chest drains placement after VATS: through a separate port or through the single incision

incision can be enlarged with 0,5-1cm any time, especially for manipulation or extraction of a large, bulky resection specimen.

- *non-deflated lung*

In such cases after checking the endotracheal tube and the cuff, bronchoscopy can help reposition the tube. Other options are to continue on intermittent lung ventilation, in the same manner as we collaborate with anesthesiology team when performing lung resections through thoracotomy (classic/open thoracic surgery) (17,18).

Chest drain after VATS

- Chest tube – placed in uniportal incision, or in one of the ports in multiportal VATS (*Fig. 9*);
- Should be removed as soon as possible (as soon as they are not necessary).
- Alternatives:
  - o no chest tube;
  - o small posterior catheter.

Learning curve and training

New techniques and surgical approaches are often regarded in the beginning with skepticisms (17). VATS has become in our days an established method to address thoracic pathologies. There is somehow a steep learning curve that is mostly conditioned by instrument resources, stapling devices and number of cases performed. One logical path, especially in uniportal VATS, is starting small and working progressively towards anatomic lung resections and to more challenging

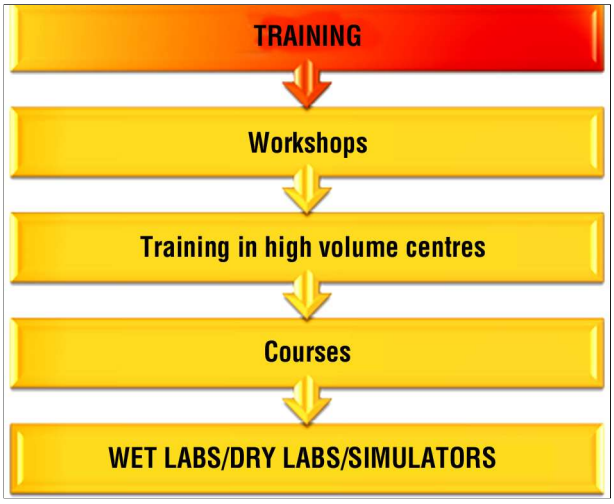

Figure 10. Training path for VATS

cases. Wedge resections are the best training "tool" for VATS resection skills. There are different studies that show the need to perform a certain number of cases by VATS in order to achieve a performance plateau and this number is considered in between 30 cases to 60 cases for experienced surgeon (18,19). It is highly advisable that VATS should be thought by experienced surgeons in both VATS and open surgery, and we followed this path in our team (20).

One of the great advantages of VATS training is the learning process. It allows for a broader auditorium in the operating room and training multiple residents on the basic steps of the surgical technique at once by direct visualization on the screen. However, in order to fully benefit from it there is still need for standardized courses as part of the training program and proper evaluation of competence/ accreditation by formalizing training in VATS (*Fig. 10*).

Conclusions

VATS is an established approach for thoracic pathologies. Either if it is multiport or uniportal, experienced surgeons in open thoracic surgery can have a smooth transition to minimally invasive surgery if given the proper instruments and training. Starting every case by a minimally invasive - video assisted approach contributes to

the consistency of the training even though increases the rate of conversion in the beginning. Technology devices evolve fast and imply more and more crossing the borders of our anatomical territories so the more VATS will evolve we will see a more diverse planning and caring-out of the treatment plan and multi-disciplinary teams will become the standard in treatment for every patient.

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Conflict of Interest

All authors have no conflict of interest to declare.

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