# The evolution of the contemporary thoracic surgeon: open surgery versus video-assisted thoracic surgery teaching—a clinical practice overview

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**Abstract:** During the past few decades, thoracic surgery has been in constant evolution from open to more refined minimally invasive surgery techniques. Teaching and learning, in parallel with proficiency, competence and mastery are subject of debate nowadays. The aim of this paper is to describe the role of open surgery and video-assisted thoracic surgery (VATS) during training of the contemporary thoracic surgeon. The authors describe the learning process in different areas and phases throughout the paper. Open surgery, although less and less frequent, mainly for simple procedures, should not be under evaluated as it provides a unique source of learning opportunities. VATS, although globally adopted as the gold standard, must be part of any training program. Both open surgery and VATS provide complimentary learning methods and techniques and should happen simultaneously, not in a competitive way. Globally, despite the efforts from some institutions and experts, most countries do not present a unified and standardized approach to teaching new procedures. Introduction of standardized methods for quantification of training are recommended. Simulators, dry and wet labs and step-by-step programs should be implemented. The authors recommend implementation of surgical learning programs that have a rationale in their core that involves gradual evolution, including both open surgery and VATS to complement each other, and to create a training that is simultaneous and not competitive.

**Keywords:** Thoracic surgery; open surgery; video-assisted thoracic surgery (VATS); teaching; learning

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## Introduction

### *Background*

During the past few decades, thoracic surgery has been in constant evolution from open to more refined minimally invasive surgery techniques. Nowadays, we have a great number of thoracic surgery centers performing more than 50% of surgeries for lung cancer using thoracoscopic techniques, with the associated advantages many times reported in the literature (1).

Historically, a thoracic procedure was the first surgery ever described: In the *Book of Genesis*, chapter II, verses 21 and 22, "*And the Lord God caused a deep sleep to fall upon Adam, and he slept: and he took one of his ribs, and closed up the flesh instead thereof*", "*And the rib, the Lord God had taken from man, made he a woman, and brought her unto the*

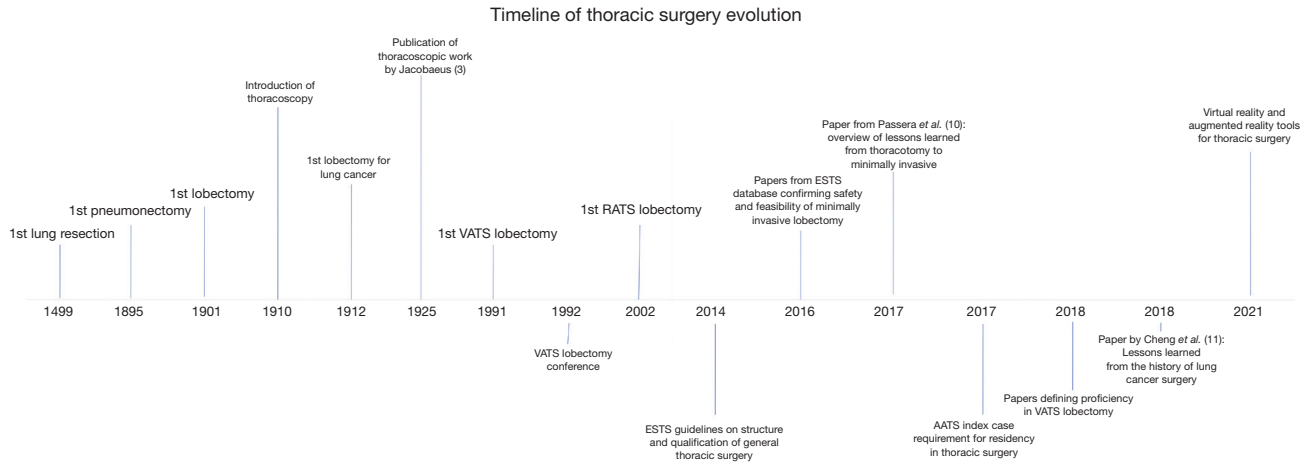


**Figure 1** Timeline of thoracic surgery evolution (3,10,11). VATS, video-assisted thoracic surgery; RATS, robot-assisted thoracic surgery; ESTS, European Society of Thoracic Surgeons; AATS, American Association for Thoracic Surgery.

*man*" (2). Ever since, thoracic surgery evolved along with medicine and clinical practice as a whole. In 1499, the first lung resection is reported in Parma, by Rolandus, after he resected a piece of lung infected with worms between two ribs (3).

Afterwards, the first pneumonectomy and lobectomy are reported before the introduction of tracheal anesthesia and double lumen tubes. In 1985, Macewen reported the first pneumonectomy on a patient who survived (4), and 6 years later, the first lobectomy is described.

Thoracoscopy was first introduced in 1910, by Professor Hans Jacobaeus (3), who published in 1925 his thoracoscopic work on staging of tuberculosous pleuyrisy, pleural effusions, empyema and pneumothorax.

Continuous evolution on anesthesia and surgical technique led to the first video-assisted thoracic surgery (VATS) meeting in 1992, held in San Antonio, organized by the Society of Thoracic Surgeons (3). Two years later, one of the first series describing safety and feasibility of the VATS lobectomy is published by McKenna (5).

The new century is marked by an increase in surgical capability, with less invasion and increased outcomes. The first lobectomies by robotic techniques were reported in 2002 (6).

Finally, in recent years, the evolution in artificial intelligence tools and simulation-based training to increase teaching and learning capability has been marked (7-9).

In *Figure 1*, we describe a timeline summary of thoracic surgery evolution.

### *Knowledge gap*

One can find in the literature papers (10-12) narrating on the current status of minimally invasive thoracic surgery that report evolution of the technique, from thoracotomy to thoracoscopy, and current issues to provide less invasive, safer procedures and straightforward recoveries, reducing surgical morbidity and mortality. However, the issue of how to teach and learn has been scarce in the literature.

The issue of training, gaining proficiency and mastery of minimally invasive surgery is subject of intense debate nowadays.

Every country regulatory entities have been stipulating minimal case numbers in every thoracic surgery area in order to certify trainees for independent practice, using the Halstedian model of surgical training based on a period of apprenticeship (13).

The American Board of Thoracic Surgery, in 2017, established 25 VATS lobectomies as the minimum for eligibility in the general thoracic surgery career choice (14), while the European Society of Thoracic Surgeons (ESTS) recommends that trainees should be exposed to at least 25 VATS lobectomies per year and qualified surgeons should have a volume of at least 20 VATS/robotic lobectomies per year (15).

Although these numbers try to establish a pattern for training, we know that every surgeon will have its own struggle during training, with some becoming more capable than others with the same experience, because the training

is affected by other factors. The exposition to open surgery before VATS training is one issue that we will explore in this paper.

Learning and assessing competence are two main questions. Traditionally, yearly evaluations are performed to assess evolution and competence, although some residents may find it difficult to have evaluations 1 year apart from each other. Depending on center volume, residents may struggle to achieve their goals. Frequent assessment, debate of surgical portfolios may be a useful tool to keep confidence and self-awareness of progress.

As Toker put it, from "*learning to fly to becoming a war pilot*" (16), illustrate the pathway to become a thoracic surgeon. Proficiency, competence, and mastery are three different levels of comprehending surgery. Self-perception, resilience, theoretical and technical skills are essential during this pathway, as one will never reach mastery in the absence of one of these cumber stones. Further studies are still needed to clarify the case volume requirements for each level of competence (17).

"*See one, do one, teach one…not anymore*" as Brown writes (18) in a comment to VATS training. Although familiar to us all, this ancient model who relied on every surgeon's ability to self-learn is outdated, as technology now gives us tools to train and teach without compromising outcomes and safety.

The path to become a contemporary thoracic surgeon should include a step-by-step approach, with gradual increase in the complexity of gestures performed, by performing parts of a surgery in a planned pathway. Self-perception of evolution, in parallel with theoretical competence, as the increase in consistence of gestures or small procedures performed, should be noted, and assessed.

During residency or fellowships, self-perception of competence is not always easy. Surgical societies are focusing on continuous education and the guarantee of surgical skills according to strict quality criteria. In this way, in Denmark, Petersen *et al.* (19) wrote a tool to assess competence in a VATS lobectomy learning program, with the main goal of standardization and certification of the learning process.

Regarding surgical competence, the authors assessed general surgical skills such as respect for structures and tissue, and surgical abilities in general; and skills specific to the lobectomy such as dissection of veins and arteries, hilum approach and lymph node dissection.

Alongside with surgical competence, theoretical competence is as important, although it is not the scope of this paper.

The authors will divide the learning process in five fundamental areas that will be further discussed in detail.

Those areas are:

- ❖ Knowledge of the surgical steps and its visual assessment;
- ❖ Visual assessment of anatomy and identification of structures;
- ❖ Respect of tissue fragility and dissection techniques;
- ❖ Intra operative complications management;
- ❖ Ability to plan a surgical procedure from the above learned grounds.

From these five areas, some are better learned during open surgery and others during VATS.

In 2014, ESTS published the European guidelines on structure and qualification of general thoracic surgery (15). In this document, regarding training, ESTS recommends that every resident should be exposed to a large volume and variety of cases in an institution of at least 300 cases yearly. The resident should perform at least 100 surgeries as first surgeon, according to the European Union of Medical Specialists (UEMS) European Board of Thoracic Surgery (EBTS) criteria. Exposure to specific areas such as lung transplantation or esophageal surgery is recommended, although this may represent the need for the residents to spend a part of their training time in another center, which the authors defend of utmost importance for the adequate training of a modern Thoracic Surgeon.

### *Objective*

With this paper, we aim to assess tools and ways to better improve teaching and learning technical capabilities during thoracic surgery, and also to describe the role and impact of exposure to open surgery and VATS during training of the contemporary thoracic surgeon.

## Teaching and learning in thoracic surgery

### *Teaching goals and methods*

The main goal while teaching surgery is to provide the opportunity to learn without compromising patient safety.

Many methods are available for teaching, such as step-by-step programs, watching recorded procedures, tutorial videos, live surgeries, simulators and dry or wet labs. All these methods have the purpose of providing safety and confidence when the time comes for the one in training to

perform a real-life surgery.

The use of simulators, although not globally adopted, has been growing worldwide. Some authors have been reporting the validity of such simulators (7,20,21). The use of a simulator in the early steps of a learning program may provide valuable input on general surgical skills as well as providing knowledge on the procedure if the simulator is adequate for general thoracic surgery.

Data on the number of gestures with each hand, hand speed, errors and precision are given to the trainee in an active feedback environment, with gradual increase in scores and, consequently, better performance. The ability to use both hands simultaneously, with slow speed, is of paramount importance in the development of a competent thoracoscopic surgeon.

The use of this device is strongly encouraged and may help to enhance progress on a VATS lobectomy learning curve (20).

Wet and dry labs provide another step on the learning process because they add to the training scenario the tissues and anatomical relationships between structures (22). Live animals provide excellent training scenarios, although the availability is limited, and there is no opportunity for repetition training as in a simulator, where a trainee is free to perform around 10 procedures in a single training session. Other limitations of animal surgery are the anatomical differences, such as barrel-type chest or elevated diaphragm (20), ethical concerns and sustainability issues.

New technologies including virtual reality, mixed and augmented reality have been object of research and will certainly play a major role in the future. The use of virtual reality to reconstruction and preoperative planning of the surgery have shown to be useful to improve skills of anatomical identification of structures and planning of the surgical procedure (8,9). Mixed reality and augmented reality tools will be helpful in identification of lesions and surgical margins decreasing the rate of error in lesion localization and positive margins (23).

The authors believe that the following decade will be rich in technological innovation and implementation of tools that will help minimize human error.

### *Open teaching*

Open surgery is vital in any learning program. Visual and tactile assessment of structures provide invaluable feedback to the trainee in the learning process, as well as three-dimensional (3D) perception of anatomical relationships.

In the recent era, with the growth of minimally invasive thoracic surgery programs all over the world, open surgery has become scarce in many centers, almost none for simple cases in centers with expert level of surgical differentiation. Nowadays, open lobectomies for early-stage lung cancer are less and less frequent. However, when needed, open surgery for complex procedures is always an excellent learning opportunity. Trainees can perform small gestures that will help them to integrate the tactile sensation while doing VATS with those felt while assisting and interacting in open surgery.

The main advantage of learning during open surgery is the ability to train fine dissection gestures, visual assessment of structures and anatomical relationships with active feedback from tactile perception. The limitation may be limited visualization—especially if the trainee is in the position of 2nd assistant.

The main goals during open surgery for teaching and learning are:

- Open and closure of the thoracotomy;
- Improvement of fine dissection gestures;
- Tactile perception of tissue texture and frailty;
- Increased 3D perception of anatomy and relationships between structures;
- Training of sutures in the chest cavity.

Although these are general learning achievements for open surgery, the authors enhance skills development for sutures and complication management as an advantage for teaching in open surgery.

Regarding sutures, usually the first contact is to suture in an academic environment, usually a dry lab. After learning suture techniques, it is fundamental to apply those skills in the patient. Chest wall suturing and closing, repeatedly, is a basic but essential training step for more advanced suture techniques. Afterwards, adding complexity due to the need of long instruments, smaller wires, and increased distance between the thoracotomy and the target, is the next step. This training will increase perception of the structures to be sutured, most frequently the pulmonary artery or airway, and create the basic experience to evolve and even be prepared for suture in VATS scenario when needed. Transition from training to reality should be gradual to keep confidence and safety.

In thoracic surgery, the most frequent sutures and end-to-end anastomosis between structures of different sizes, such as in vascular or bronchial sleeve lobectomies or pneumonectomies. To acquire mental perception of structural anatomy and relations is vital to be able to

 

perform these procedures.

During open surgery, complication management, such as bleeding with need for compression, vessel control and hemostatic sutures, provide another fundamental basis to become proficient or master of any surgical procedure. Keeping the patient safe should be always the priority during surgery. In our opinion, it is fundamental to be at ease with complication management during open surgery before being ready to perform VATS safely independently.

Although open surgery is, in centers with expertise in VATS, reserved for more advance surgery and training in open and VATS occurs quite simultaneously, the authors defend that surgical exposure by observing complications management (open and minimally invasive) will give the right insight to solve it or to call for help. Sometimes, the key is to identify the risk and call for assistance. Thoracic surgery is not a solitary number.

The specific scenario of lung transplantation provides an invaluable learning moment. This maximal invasive surgery is unique regarding the approach to hilar and mediastinal anatomy and the relationships between structures. It also provides teaching on vascular and bronchial sutures.

ESTS guidelines on structure and qualification of general thoracic surgery (15) refer specific needs before training in this area, such has previous extensive experience with lung resection surgery and mediastinal surgery of at least 150 cases and experience with cardiopulmonary bypass and extracorporeal membrane oxygenation (ECMO). They also recommend 10 harvest procedures as adequate to proceed lung procurement autonomously and exposure to 30 lung transplantation surgeries to be ready for exposure to more complex scenarios.

Lung procurement, back table preparation of the graft and pneumonectomy and implantation surgery are all very exciting for every thoracic surgeon in training.

The training for lung procurement should include 10 assisted procedures with increased exposure and where the one in training will gradually perform more. The authors recommend five autonomous harvesting procedures with supervision, before going autonomously.

During implantation, after preparation and trimming, the airway and vascular sutures provide excellent opportunities to train. Performing parts of the anastomotic suture until proficiency is acquired and the one in training is able to implant properly in a safe time is recommended. As exposure increases, gradually, the one in training should be able to perform the pneumonectomy and prepare structures for anastomosis. The preparation of the structures should start with preparation of the graft in the back table and then preparation of the hilum, which is usually the final step of training.

Contact with experienced centers in lung transplantation during residency for a period of 3 to 6 months is strongly encouraged as it provides valuable experience and exposure even if the one in training will not pursue this area in the future. Experience approaching the hilum, intrapericardial vascular structures or mastering cardiopulmonary bypass and ECMO are invaluable in the portfolio of any thoracic surgeon and will be extremely useful handling serious bleeding complications or excising complex tumors with mediastinal invasion.

### *VATS teaching*

In past decades, VATS has been proven to be the gold standard approach for almost all general thoracic surgery procedures. It has proven to be safe, cost effective, and easily applicable even in underprivileged countries. It provides quicker recovery, less pain and hospital stay time, with the same oncological outcome and earlier to return to active life (1,24-26).

Worldwide adoption of this technique has been slow, what may have been a barrier for learning opportunities in the youngest surgeons, because experienced ones were facing their own learning curve.

Many papers regarding proficiency and step-by-step programs can be found in the literature (13,17,25-31).

Nowadays, most of residents are exposed to VATS lobectomies and every kind of VATS procedures early in their training programs. The papers published agree on a gradual learning curve starting with less complex procedures before being trained for the VATS lobectomy.

ESTS (15) recommends that residents are exposed to every kind of VATS procedure, from simples to complex lobectomies, including being exposed to at least 25 lobectomies per annum. The society also recommends learning by performing simple procedures and evolving in complexity, with the aim of performing approximately 100 simple cases before starting a VATS lobectomy training program.

Main advantage of thoracoscopic surgery teaching is increased visualization and ability to learn even if only observing out of the disinfected field. This allows for better understanding of the surgical procedure and visual anatomy.

Step-by-step approach was the classic approach for major technique changes.

VATS lobectomy has substantial differences from open lobectomy, specifically (19,20,25):

- Surgeon position from posterior to anterior;
- Transforming a two-dimensional (2D) image into a 3D mental perception;
- Dissection begins at the hilum instead of fissure;
- More blunt and less fine dissection;
- No "flipping" maneuver;
- Ergonomic adaptation to endoscopic instruments.

These changes were traditionally accompanied by a gradual decrease in incision size and dislocation to anterior until we reach the utility port.

Simulators and cadaveric or animal surgery may help enhance the effectiveness of a learning curve and shorten the transition period without compromising patient safety and outcomes. Exposure to VATS since the beginning of the residency also brings familiarity and comfort to the surgeon in training, especially if exposed to a gradual increase in complexity. The senior surgeon teaching VATS can also control all steps safely guiding the trainee through the procedure.

Regarding complications, a common concern during teaching and learning minimally invasive surgery is how to handle complications without compromising safety (24,32).

The main issue is, if the one in training is the less experienced, how does the teaching surgeon prevent complications and how does one handle them if they happen? The pulmonary artery may lead to catastrophic complications in the case of massive hemorrhage in the VATS scenario. Experience along with skills is mandatory to control it (19,32). From compression techniques to endoscopic suture, many solutions may come when facing a bleeding problem. The key factor is to preserve calm and focus, and then control and repair. Opening is always a solution, and one should always keep in mind that conversion does not mean failure. Patient safety first.

The teaching surgeon should be responsible to maintain good environment, teamwork and provide the learning one with confidence to go through with the task in hands safely. Danger gestures and imminent complications should be anticipated or quickly controlled, even if this requires the teaching surgeon to take over the procedure. Gradual learning and perform steps of a surgery is encouraged and should not be seen as a failure by the ones in training.

Previous experience with open surgery is another common issue. Passera *et al.* published a paper on lessons learned from full thoracotomy to VATS (10). The author indicated that the minithoracotomy has a possible transition technique, as the surgeon adopts some steps in the VATS approach, such as anterior position and dissection angle. The transition to small incision and full thoracoscopic, even uniportal, should than be natural as long as surgical principles of dissection and compliance to the new technologies is preserved. A best evidence topic published in 2015 (33) addressed this question. Seven papers were studied and found no differences in surgical outcomes comparing junior surgeon with and without previous experience and states that prior experience does not eliminate the need for the learning curve. However, some papers reported that previous surgical experience led to shorter operative times in the papers analyzed. This fact may be due to increased confidence and theoretical knowledge on the procedure that would naturally be added by increased experience.

Nevertheless, the authors believe that classic postero-lateral thoracotomy with posterior positioning will always play a role for complex procedures.

### *Limitations*

The subjects approached throughout this paper are presented as a retrospective review of clinical practice, so we consider this as a limitation.

Although we provide a guide to orientation of teaching methods, no valid prospective studies are presented to validate the efficacy of such methods.

Learning and teaching are a set of skills that need to be adopted to each teaching surgeon and to each surgeon in training.

Future studies evaluating different methods are strongly motivated to help the community of thoracic surgeons to improve teaching skills and guarantee a strong base for future development.

## Conclusions

VATS lobectomy was first reported in 1992 (34). This surgical technique is widely adopted and is becoming the gold standard approach in thoracic surgery.

However, knowledge of open surgery should not be under evaluated as complex procedures that demand such an approach will always exist.

Globally, although some efforts on some institutions and experts, most countries do not present a unified and standardized approach to teaching new procedures.

Introduction of standardized methods for quantification of training are recommended. Simulators, dry and wet labs

and step-by-step programs should be implemented.

The authors recommend implementation of surgical learning programs that have a rationale in their core that involves gradual evolution, where open surgery and VATS complement each other, and the training is simultaneous, not competitive.

The room for simple open procedures is shrinking and it should not be done in favor of training, as it does not benefit the patient in any way.

Surgery is in constant change and every surgeon should keep an open mind to improvement. New generations show improved skills in handling advanced technologies and surgery will evolve in this way for next decades, mainly regarding robotics, minimally invasive approaches, and even logarithmic machine learning procedures with only human supervision.

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