Device and technology helping to teach video-assisted thoracic surgery

Eleonora Della Beffa[1,2#], Paraskevas Lyberis[2#], Giulio Luca Rosboch[3#], Ludovica Balsamo[1,2], Federico Femia[1,2], Paolo Olivo Lausi[1,2], Enrico Ruffini[1,2], Francesco Guerrera[1,2^]

[1]Department of Surgical Science, University of Torino, Torino, Italy; [2]Department of Thoracic Surgery, Azienda Ospedaliera Universitaria Città Della Salute e Della Scienza di Torino, Torino, Italy; [3]Department of Anaesthesia, Intensive Care and Emergency, Azienda Ospedaliera Universitaria Città Della Salute e Della Scienza di Torino, Torino, Italy

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[#]These authors contributed equally to this work.

Correspondence to: Francesco Guerrera, MD. Department of Thoracic Surgery, Azienda Ospedaliera Universitaria Città Della Salute e Della Scienza di Torino, Torino, Italy; Department of Surgical Science, University of Torino, Corso Dogliotti, 14 10126 Torino, Italy. Email: francesco.guerrera@unito.it.

Abstract: Despite the evident and evidence-based clinical advantages of the video-assisted thoracic surgery (VATS) approach, traditional thoracotomy is still the favored method for major pulmonary resections, mainly due to the length of the learning curve for thoracic surgeons. Acknowledging the current teaching and learning challenges for both young trainees and mentors in achieving the necessary skills in order to perform VATS procedures safely, we reviewed available literature looking for different simulation tools and teaching strategies that might help young surgeons in the task. PubMed was explored for English language articles published between 2005 and 2020 reporting on different techniques used in surgical training to develop necessary surgical skills in minimally invasive surgery. The research was conducted using the following medical subject heading terms: "VATS"; "thoracic"; "surgery"; "training"; "residency"; "simulation"; "simulator"; "virtual reality"; "video-assisted thoracoscopic surgery"; "lobectomy"; "learning curve". It is believed that integrating simulators into the usual physical training model might represent an effective solution to help junior surgeons overcome and shorten the initial learning curve, reducing, therefore, the volume of training time required in the operating room. Simulation systems, in addition to on-field supervised direct operating room experience, might be helpful in allowing both junior and senior surgeons to improve their soft and hard skills, reducing the broad minimally invasive surgery learning curve.

Keywords: Video-assisted thoracic surgery (VATS); lung cancer; 3D; virtual reality (VR); simulation

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Introduction

Lung cancer remains one of the most common causes of cancer death, representing indeed the first cause of death (along with stomach and colon cancer), with over 2 million new lung cancer diagnoses in 2020 (1).

According to the literature, radical surgical resections represent the gold standard treatment for early-stage non-small cell lung cancer. Traditionally, anatomic lung resections have been performed using a thoracotomy approach. Nevertheless, currently, minimally invasive

^ ORCID: 0000-0002-4125-4379.

techniques, such as video-assisted thoracic surgery (VATS) or robot-assisted thoracic surgery (RATS), have an essential role and are increasingly used as an approach of choice for early-stage non-small cell lung cancer treatment. Their multiple advantages comprise lower postoperative pain, improved quality of life, shorter hospital stay, fewer complications, enhanced shoulder function recovery, and better tolerance of complementary treatments (e.g., radiotherapy, chemotherapy) (1-7).

Despite the obvious clinical advantages of the VATS in surgical practice, conventional thoracotomy is still the favored method for major pulmonary resections in many hospitals and institutions (5).

The systematic adoption of VATS procedures in surgical practice has been slow in many centers. It has been observed that this phenomenon might be due to a shallow learning curve for both junior thoracic surgeons and more experienced surgeons that may be more comfortable with the traditional thoracotomy approach (8).

Nowadays, there is an increasing interest, among surgical communities, in ensuring a high standard and continuous education towards developing surgical skills according to standardized quality criteria such as the VATS assessment tools (9) in order to provide the best possible standard of care to patients and a solid educational standard to reach for junior thoracic surgeons and trainees.

The purpose of this review is to describe and discuss the current literature evidence about new technologies that might enhance the development of necessary surgical skills and technical competence in minimally invasive surgery both in the operating room and pre-clinical simulation settings. The investigation mainly focused on minimally invasive thoracic surgery, particularly VATS lobectomy, considered the standard surgical treatment for early-stage non-small cell lung cancer.

Methods

PubMed was explored for English language articles published between 2005 and 2020 reporting on different techniques helping surgical trainees develop necessary surgical skills in minimally invasive surgery in both the operating room and pre-clinical simulation settings. The search used combinations of medical subject heading terms such as "VATS"; "thoracic"; "surgery"; "training"; "residency"; "simulation"; "simulator"; "virtual reality"; "video-assisted thoracoscopic surgery"; "lobectomy"; "learning curve". Reference lists of papers were also reviewed to find additional studies of interest.

Two revisors reviewed the find articles, and in the end, 13 papers were selected.

Summary

The aim of clinical and surgical procedures simulation is to produce operative scenarios in a realistic environment to enhance positive feedback and assessment processes in trainees in order to develop an ideal educational environment where procedures are reproduced to be performed in a safe environment. This setting encourages residents and junior surgeons to learn through experimentation and try-and-error, with the ability to repeat and practice without compromising the clinical outcome.

These technologies range from simple demos through screen-based interactive games—such as fiber-optic bronchoscopy navigation (10)—to partial task trainer devices designed to allow trainees to practice complex procedures to full environment simulation (FES) using high-fidelity simulators.

All of the reviewed articles are summarized in *Table 1*.

Skills development

Several studies have been proven to promote an acceptable skills transfer from virtual reality (VR) training to performance in the operating room, allowing trainees to reach the on-field clinical and surgical training with a broader range of competencies, therefore reducing the intraoperative risks.

The minimum number of procedures and the time needed to get familiar with a new surgical technique for a young surgeon have been discussed in many reports. Considering VATS lobectomies, it is believed by most authors that the learning curve consists of at least 50 VATS lobectomies performed as leading surgeons (8) or more than 200 cases if there is no available mentor guidance (11).

It is believed that integrating simulators into the classic on-field operating room training model might represent an effective solution to support junior surgeons overcome the preliminary learning curve, decreasing the amount of training period required in the operating room, even though there still isn't an established consensus evidence (11).

In order to speed up and improve this delicate skill-learning journey, new technologies can be helpful if adequately supported by a proctor-guided on-field surgical experience.

Table 1 Overview of the studies

References	Author, title, journal and year	Key points and patients selection	Conclusions
(8)	Petersen RH, Hansen HJ. Learning thoracoscopic lobectomy. *Eur J Cardiothorac Surg*. 2010	The study compares results of VATS lobectomies performed by a training consultant and an experienced surgeon showing better results for the training consultant regarding air leak, chest tube duration and LOS	VATS procedures can be taught in highly experienced centers
(10)	Nilsson PM, Naur TMH, Clementsen PF, *et al.* Simulation in bronchoscopy: current and future perspectives. *Adv Med Educ Pract*. 2017	A review on simulation training for bronchoscopy considering how to enhance competence and how to develop cheap alternatives in bronchoscopy simulation	Bronchoscopy simulation is effective. Cheaper simulators with new features will be available in the future maybe using 3D printing techniques
(11)	Nashaat A, Sidhu HS, Yatham S, *et al.* Simulation training for lobectomy: a review of current literature and future directions. *Eur J Cardiothorac Surg*. 2019	The article describes many simulators teaching trainees different skills both technical and non-technical	It appears to be an important lack of studies validating simulators and teaching systems for teaching lobectomy
(12)	Vyas RM, Sayadi LR, Bendit D, *et al.* Using Virtual Augmented Reality to Remotely Proctor Overseas Surgical Outreach: Building Long-Term International Capacity and Sustainability. *Plast Reconstr Surg*. 2020	An augmented reality U.S. proctoring system was tried to help Peruvian surgeon learn cleft palate surgery safely. Significant improvement was observed in cleft lip repair	Augmented reality high tech system can be a helpful instrument in teaching surgical techniques
(13)	Jensen K, Ringsted C, Hansen HJ, *et al.* Simulation-based training for thoracoscopic lobectomy: a randomized controlled trial: Virtual-reality versus black-box simulation. *Surg Endosc*. 2014	Surgical residents were trained on VR. Systems or black-box simulator and then asked to perform a VATS lobectomy on a porcine model. The black-box group was significantly faster if compared to the VR group	Black-box training appears to be more effective than VR but it has to be considered that the simulators used in the study was not a dedicated thoracoscopy system
(14)	Bjurström JM, Konge L, Lehnert P, *et al.* Simulation-based training for thoracoscopy. *Simul Healthc*. 2013	A self-guided trainee group was compared to an educator-guided group before performing a wedge resection on an animal training model showing no significant difference between the educator guided group and an experienced surgeon	Trainee can perform an acceptable wedge resection in a simulator if adequately trained by experienced personnel
(15)	Iwasaki A, Okabayashi K, Shirakusa T. A model to assist training in thoracoscopic surgery. *Interact Cardiovasc Thorac Surg*. 2003	The article describes a thoracoscopic simulator with circulation blood tested in a VATS conversion and compared to wet labs	The simulator appears to be useful in the training of thoracic surgeons, allowing to decrease the number of experiments on animals
(16)	Sato T, Morikawa T. Video-assisted thoracoscopic surgery training with a polyvinyl-alcohol hydrogel model mimicking real tissue. *J Vis Surg*. 2017	The article describes a simulator using hydrogel as main material in the attempt of simulating chest anatomy and texture	
(17)	Fann JI, Feins RH, Hicks GL Jr, *et al.* Evaluation of simulation training in cardiothoracic surgery: The Senior Tour perspective. *J Thorac Cardiovasc Surg*. 2012	Experienced surgeons tested different surgical simulators including both thoracic and cardiac procedures concluding that the simulator tested might not provide a real-like experience	Experienced surgeons might improve simulation-based learning in cardio-thoracic surgery

Table 1 (*continued*)

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References	Author, title, journal and year	Key points and patients selection	Conclusions
(18)	Tedde ML, Brito Filho F, Belmonte Ede A, *et al.* Video-assisted thoracoscopic surgery in swine: an animal model for thoracoscopic lobectomy training. *Interact Cardiovasc Thorac Surg*. 2015	Swine have always been used for surgical training with actually no studies reporting the peculiarities of this kind of simulated VATS lobectomy	To enhance this kind of simulation-learning the specific aspects of the swine model in VATS lobectomy should be further assessed
(19)	Jensen K, Bjerrum F, Hansen HJ, *et al.* Using virtual reality simulation to assess competence in video-assisted thoracoscopic surgery (VATS) lobectomy. *Surg Endosc*. 2017	LapSim was used to simulate a VATS right upper lobe lobectomy by different trainees with different expertise levels	The LapSim appeared to be useful tool in teaching a RUL and in evaluating the trainee expertise on the technique
(20)	Konge L, Petersen RH, Ringsted C. Developing competency in video-assisted thoracic surgery (VATS) lobectomy. *J Thorac Dis*. 2018	The article demonstrates how it appears to be both safe and feasible to teach to junior trainees using simulation tools and then to perform the learned techniques with close supervision in the clinical setting	Simulators allows young surgeons to exercise in a safe setting and learn how to handle complications
(21)	Divisi D, Barone M, Zaccagna G, *et al.* Video-assisted thoracoscopic surgery lobectomy learning curve: what program should be offered in a residency course? *J Vis Surg*. 2017	Trainee can benefit from VATS simulators and direct observation of surgeries and videos with good evidence but still the application of this learning techniques remain poorly adopted in surgical education	

VATS, video-assisted thoracic surgery; LOS, length of stay; VR, virtual reality; RUL, right upper lobectomy.

VR training

Between 2019 and 2020, Vyas *et al.* investigated the VR associated with proctor guidance in cleft lip repair surgery, observing that tech tools such as augmented reality enable surgeons to have a live attendance of an expert surgeon that effectively scrubs in and guides the operation ensuring quality outcomes and helping improve the trainee operative techniques, accelerating surgical knowledge transfer. Still, a hands-on proctor remains essential to achieving surgical autonomy for trainees and junior surgeons (12).

But can simulation training supplement or replace conventional minimally invasive surgical training in junior surgeons with limited previous experience?

Discussing VATS lobectomy, other research groups have experimented with different surgical training systems approaches using both physical and virtual or augmented reality simulation models, with exciting results.

Jensen *et al.* (13) selected 28 surgical residents previously trained on a VR nephrectomy module or traditional black-box simulator training to perform a thoracoscopic lobectomy on a swinish model.

The VR group was tested in bowel mobilization, kidney hilar dissection, and vessel dividing in order to simulate pleural adherences dissection and freeing of the lower pulmonary ligament in a thoracoscopic lobectomy. The black-box group was tested by threading a peg through ten loops fixed at different depths and angles, collecting matches from plastic cups with both left and right hands according to the matches colors, and placing them into the thumb of a surgical glove. When performing the VATS lobectomy, the researchers observed that the black-box group performance was considerably speedier during the test scenario than the VR group, with no difference in complications such as bleeding or anatomical and non-anatomical errors. It appeared that the proficiencies learned on the laparoscopy in a VR setting did not transfer as well to the heart and lung block as those learned on the black-box simulator (13).

Bjurström *et al.* compared four different groups (including a surgeon group, a control group, a self-guided and an educator-guided group) facing three different black-box scenarios with increasing difficulty followed by a wedge resection on a swinish lung, which was recorded and evaluated by two thoracoscopic specialists. The educator-guided group scored reasonably better than the control group and only fairly worse than the surgeons' group. The self-guided group scored no higher than the group receiving no training at all, showing the effect of the brief teaching program and the educator figure (14).

Physical reality simulators

Nashaat *et al.* (11) reviewed the existing literature searching for different VATS and open lobectomy simulators. Different VATS lobectomy physical reality simulation models were described. Iwasaki *et al.* (15) described replaceable pulsatile pulmonary vessels and lung parenchyma made from polyurethane within a plastic thorax with high-quality simulation, easy handling, and low costs; Sato *et al.* (16) built a hydrogel lung model into an artificial rib cage simulating actual tissue texture and also allowing the use of electrocautery and energy devices; Fann *et al.* (17) tested a simulator based on a porcine heart-lung block inserted into the thoracic cavity of a mannequin with fixed working ports *in situ*, asking 13 experienced surgeons to perform different tasks such as hilar dissection, VATS lobectomy, rigid bronchoscopy, tracheal resection, esophageal anastomosis, and sleeve resection with highly realistic and well simulated advanced maneuvers and Tedde *et al.* (18) simulated real VATS lobectomies in live anesthetized swine providing young surgeons with early exposure to actual equipment and technique despite the ethical dilemma. However, most of these simulation models still need to be assessed for validity and reliability before being fully integrated into the standard teaching method.

Moreover, VR systems such as LapSim (19) simulator for right upper lobectomy performed with the standard anterior approach were also tested. In this particular case, the study participants were asked to complete the lobectomy twice, with a five-minute break. The simulator, according to the study results, appeared to be reliable with the potential to become the first step in evaluating the proficiency of thoracic surgery trainees in VATS lobectomies (11).

Trainees' learning curve and VATS training

Virtual and physical reality simulators provide basic skills training, including camera navigation, instrument handling, instrument coordination, clip positioning, tightening knots, and vessel dissection even without supervision (14) in a controlled and pressure-free environment. Skills obtained through VR simulation training, such as additional tactile feedback, different eye-hand coordination, and adjustments in translation from a bi-dimensional video image to a 3D operative field (14), can then be safely transferred to the operating room.

The obtained surgical performance, resulting from the integration of several different training systems, has been found to be related to providing an initial expertise level that allows a safer on-field operating room experience when performing the surgery in a proctor-guided real-life situation, with a shallower learning curve.

The VATS training remains a real challenge for junior surgical trainees due to its technical complexity and the apprehension of possible complications development, such as bleeding, stapling failures, or anatomical abnormalities requiring a high expertise level or conversion to open surgery in order to be effectively and safely managed.

In this surgical setting, young trainees need to acquire a certain autonomy level in technical competencies such as vascular dissection, allowing surgery to be achieved safely for both patients and operating teams using teaching platforms including black-boxes, 3D VR or augmented reality (AR) simulators, animals (like porcine heart-lung blocks) (20) and cadaver models to prepare young thoracic surgeons to direct on-field practice operating room (21) having already performed the actual procedure steps using real instruments.

Conclusions

VATS lobectomies, are gaining increasing importance as gold standard techniques in treating early-stage non-small lung cancer as well as for other benign lung conditions requiring parenchymal resections. Therefore, increased attention to young thoracic surgeons' surgical training remains a critical point in educational strategies during residency.

Currently, it is possible to distinguish several different training models, including black-box simulators, hybrid simulators, VR simulators, augmented reality simulators, animal models, and cadaver models (22).

VR or physical reality simulation tools, in addition to on-field, supervised direct operating room experience, can allow trainees to make mistakes in a safe and negative outcome-free environment, teaching how to try to handle complications and complex case scenarios.

Always accompanied by direct supervision, introducing surgical simulators into training can allow both junior and senior surgeons to improve their technical and nontechnical skills, reducing the broad minimally invasive surgery learning curve.

To state of the art, further studies will be necessary to validate the thoracic surgery available simulation platforms ultimately and to encourage the implementation of these teaching techniques into the standard teaching common practice.

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