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Review Article

Training and precision surgery in VATS lobectomy

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Abstract: Learning and mastering video-assisted thoracoscopic surgery (VATS) is complicated and ensuring that all trainees reach a level where they can operate independently and proficient requires extensive knowledge regarding training and certification methods. We reviewed the literature regarding training in VATS lobectomy in order to evaluate the evidence and discuss the different programs in teaching VATS lobectomy, the learning curve, the role of simulation, and the role of certification and assessment in VATS lobectomy. A search performed in PubMed from their commencement to February 2019, identified 335 articles and abstracts. After reviewing all these articles, 30 articles were eligible for full text screening. We conclude that there is a need for a structured VATS lobectomy training program in every institution handling lung cancer patients. Stepwise learning where trainees prepare theoretically followed by off theatre preparation, such as learning the basic skills using virtual reality simulation and dry and wet lab simulation is essential. Once the basic skills are learned, the novice surgeons can perform minor VATS procedures and gradually perform lobectomies under supervision until reaching competency and precision in VATS lobectomy. We suggest that VATS programs should be completed with certification.

Keywords: VATS lobectomy; trainee perspective; VATS programs; simulation; non-technical skills; assessment and certification VATS

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Introduction

Video-assisted thoracic surgery (VATS) for lung cancer was introduced in 1991 (1). Since then VATS lobectomy has become an accepted procedure and emerged as gold standard for treatment of lung cancer worldwide. VATS offers several advantages, including low morbidity, shorter hospitalization, decreased pain, better outcome and better tolerance for adjuvant chemotherapy (2,3). To avoid and overcome substantial complications, thoracic surgeons must develop competence and master VATS to a precision level, where the physicians are permitted to perform procedures independently. They must have extensive knowledge and skills to operate on patients. Developing competence and then proficiency in VATS lobectomy, not only requires enough procedures to achieve consistent safety and efficacy, but also requires qualitative upsurge in knowledge, new skills and performance. The novice surgeons should be mentored and supervised appropriately until they demonstrate skills required for competency and then proficiency in VATS procedures.

There are different opinions about the caseload, time and other program requirements to achieve competence and proficiency in VATS. Some suggest that trainees must perform more than 100 minor procedures to get familiar with the surgical instruments and basic VATS skills before undertaking a VATS lobectomy (4,5). Furthermore, 25 lobectomies per year are suggested to complete learning

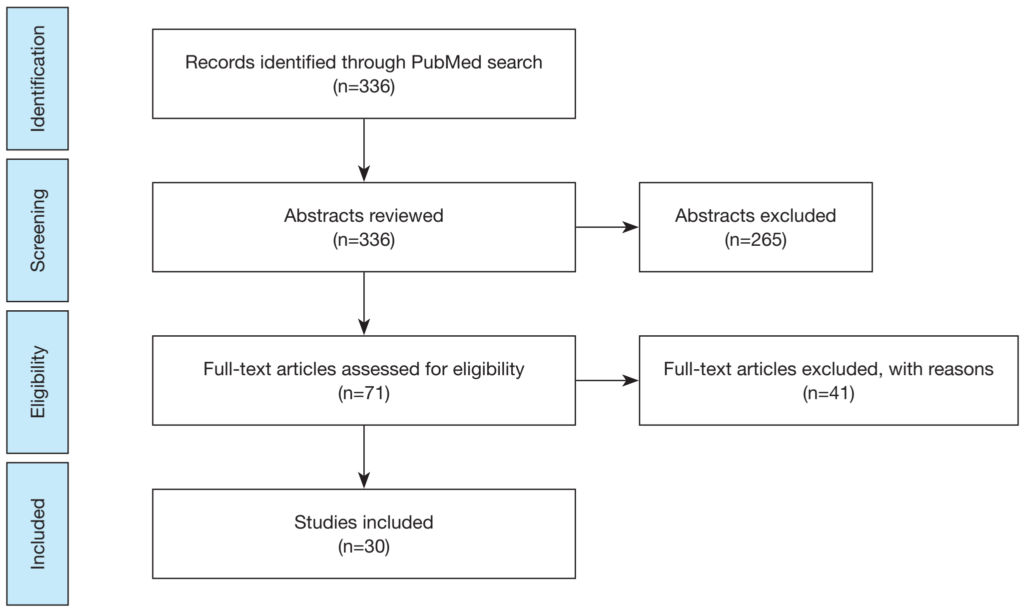

Figure 1 Consort diagram of the search strategy.

curves and retain proficiency (4,5). Would a threshold of 25 or 50 VATS lobectomies ensure that a surgeon is competent? Should a VATS surgeon have thoracotomy experience?

There are several un-answered questions about learning curves, VATS programs, the role of simulation in VATS, learning VATS under supervision, assessment tools, certification etc.

The aim of the current review was to get a narrative overview of the different VATS programs, learning curves, VATS assessment tools, role of simulation in VATS and to explore the existing evidence of training models and their efficacy.

Materials and methods

An electronic search was performed in PubMed. Articles published before April 2019 were screened and included if considered relevant. To achieve maximum sensitivity of search strategy and identify all trials, we used the following the terms: training VATS lobectomy, learning curve VATS lobectomy, VATS certification, VATS non-technical skills and VATS simulation. All the studies including VATS lobectomies and VATS learning curves published in English were included. The references of all retrieved articles were reviewed for further identification of any relevant studies. We excluded studies that we did not find directly relevant for this study (*Figure 1*).

Training and precision

Procedural expertise exhibited by a VATS surgeon is difficult to designate and classify. To qualify and practice VATS independently, it is required that physicians demonstrate competence and have the ability to perform a procedure safely and effectively. To develop competency and efficiency in VATS there is a need for structured education programs. There are many different methods to learn VATS. Surgeons can observe other surgeons, read books, see videos, read anatomical atlases, attend national and international thoracic surgery courses and seminars, perform simulation training etc.

Learning curve and preparation

Several factors influence learning curves, such as the potential number of surgeries, size of center and time between surgeries, preparation before surgery and patient selection. There is a difference in learning curve between a self-taught surgeon and a surgeon under supervision of experienced VATS surgeons. Konge *et al.* described that the learning curve can be overcome, even with limited prior experience in thoracotomy, with thorough preparation of trainees and training on

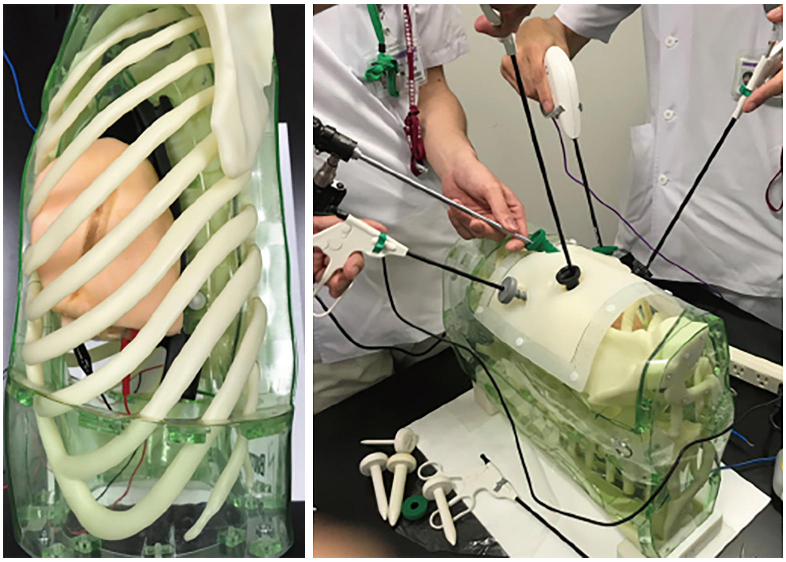

Figure 2 Dry lab. The Biotexture lung is installed inside the Biotexture thoracic cavity simulator to offer a realistic environment for surgical training. Shimada (9).

selected patients under close supervision (6). A trainee who had performed 14 lobectomies by thoracotomy was enrolled in a training program. The preparatory phase included VATS master classes with hands on practice on live pigs and a VATS lobectomy course with a validated lobectomy model and observation of VATS lobectomies both on video and in the operating theatre. The trainee practiced on a simulator, on pigs and performed more than 100 minor VATS procedures and observed more than 100 VATS lobectomies. The preparatory phase was followed by clinical practice, where suitable patients were selected, in regard to factors such as tumor localization, tumor size and absence of major comorbidities. The trainee performed 29 VATS lobectomies in a 12 months' time under supervision of an experienced VATS surgeon. None of the operations were converted to open thoracotomy and per-operative and post-operative results were acceptable.

Yao *et al.* investigated the learning curve by using a multidimensional method and compared the learning curve groups with respect to perioperative and clinical outcomes in a retrospectively reviewed prospective study (7). Sixty-seven patients underwent VATS lobectomy by one surgeon and data was analyzed by a moving average and the cumulative sum (CUSUM) method. CUSUM is a sequential analysis method, which monitors the change detection and assume that a process is stable and under control. Their result showed that peak point for operation was at their 26.th case, meaning that their learning curve for VATS lobectomy required 26 cases. Li *et al.* used the same method to analyze the learning curve of VATS lobectomy (8). They evaluated the development of proficiency in VATS lobectomy using CUSUM analysis. They concluded, to achieve proficiency in performing VATS lobectomy requires 100 to 200 cases and to procure consistency requires more than 200 cases. This result represents the learning curve of a single surgeon with five years of experience in thoracic surgery.

The role of simulation in VATS surgery

A wide range of simulations are developed to increase patient safety by improving novice surgeons' cognitive and procedural skills in VATS before they can operate on patients.

Three different types of simulations modalities are available: Dry lab, wet lab and virtual reality simulation. Dry lab simulators such as Box trainers increase the skills and enable trainees to perform and learn basic procedural skills (*Figure 2*). The haptic feedback is preserved and creates high fidelity for VATS training (10). Wet lab simulators using the pig model are very sophisticated and create a realistic setting, but are very expensive and bear ethical issues, anatomical difference, difficulties in anesthesia and have poor cardiopulmonary reserves (11). Using porcine

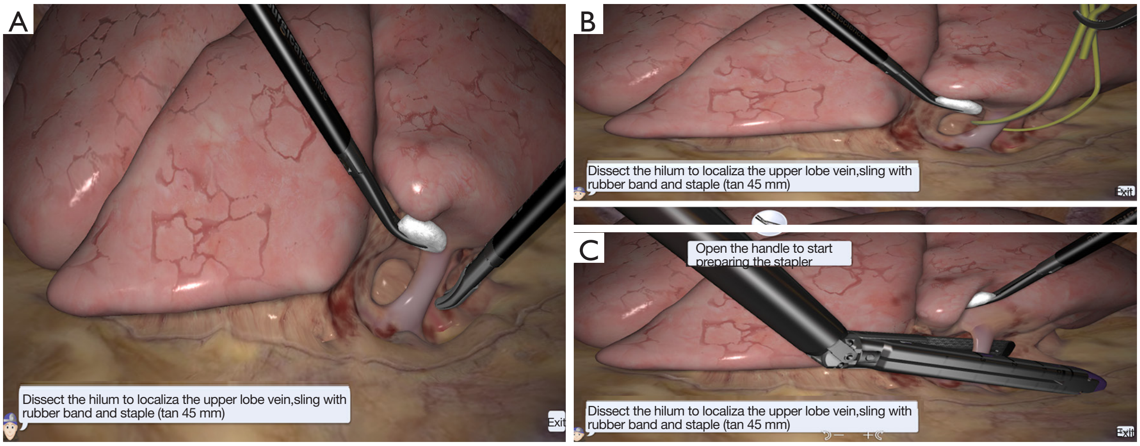

Figure 3 VR simulation LapSim®module of a right upper lobe lobectomy demonstrating the dissection of the upper lobe vein (A), slinging (B) and stapling (C).

heart-lungs tissue blocks from pigs are low cost, accessible, easy-to-prepare and reproducible tissue simulator, that can be effective in instruction to surgeons with different level of operative experience (12).

Virtual reality simulators on the other hand create a realistic setting, where trainees can develop their basic skills such as; hand-eye coordination, depth perception, movement of instruments in a repetitive manner and out of theatre environment where the trainees can achieve surgical competence before operating on patients. Simulators accelerate the learning curve (13).

Different types of virtual reality simulators such as Lap Mentor™ (3D Systems, California, US) or LapSim™ (Surgical Science, Gothenburg, Sweden) are available (*Figure 3*). The validity of simulation-based assessment and the effect of simulation-based training are evaluated and investigated by Jensen *et al.* and Bjurström *et al.* (13-15).

The assessment of competency

The assessment of competence in VATS is discussed in several studies. Konge *et al.* created an assessment tool consisting of 10 items by an expert group of physicians (16). Fifty consecutive thoracoscopic wedge resections were included and assessed blindly by two experts. They concluded that this tool for assessing performance in thoracoscopy was reliable and valid and can offer structured feedback to trainees and be used to evaluate new teaching curricula. Jensen *et al.* used a Delphi method and developed a novel assessment tool for VATS lobectomy based on a large number of internationally recognized VATS expert's consensus (17). The VATSAT (video-assisted thoracoscopic surgery assessment tool) consists of eight items. These items can support learning VATS lobectomy by providing structured feedback and help the supervisors identify when the trainees have acquired competencies for independent performance. The validity evidence for VATSAT was provided by Petersen *et al.* in a Danish nationwide study (18). They recorded 60 lobectomies performed by 18 thoracic surgeons of different level of experience; expert, intermediate and beginners. The videos were rated using VATSAT and solid evidence of validity was provided. They concluded that VATSAT could be an important aid in future training and certification of thoracic surgeons. The theoretical knowledge acquisition for VATS lobectomy shows that cognitive skills gained through theoretical testing support technical performances (19). It can also stimulate learning and encourage self-study. Savran *et al.* developed and gathered validity evidence for a theoretical test on VATS lobectomy consisting of multiple-choice questions (20). Technical skills in VATS surgery are dependent on cognitive social and personal resource skills that contribute to safe and efficient task performance and can be defined as Non-technical skills. VATS surgeons are dependent on their team. Team training with a shared mental model of the operation is an important issue. Gjeraa *et al.* identified non-technical skills for VATS lobectomy (21).

Their study identified six non-technical models. These findings contribute to three important shared mental model constructs; Planning and preparation, risk assessment, and leadership. VATS surgery is team-work and it needs planning, preparation, and risk assessment before each procedure.

Selection of patients

Accurate patient selection is crucial for a safe learning curve in VATS lobectomy. Size and location of tumor, patient comorbidity and frailty are important to ensure a low conversion rate and morbidity rate. Amore *et al.* recommend different steps in the development of a VATS lobectomy program (22). They recommend careful selection of patients in the beginning. Petersen *et al.* described in a prospective study that VATS lobectomy can be taught safely with careful selection of patients in a surgical institution experienced in VATS lobectomy (23). Consecutive VATS lobectomies were performed by two consultants; one a self-taught experienced VATS surgeon and one consultant in training for VATS lobectomies. The training consultant performed 200 minor VATS procedures prior to performing supervised VATS lobectomies. In the study period, 150 patients were operated by the experienced surgeon and 47 VATS lobectomies by the consultant in training. The patients for the consultant in training were selected, where majority of patients had early-stage lung cancer. There was no significant difference in patient outcome between VATS lobectomies performed by the experienced consultant and the training consultant, but the procedural time for the consultant in training was significantly longer.

Which programs are available and should be offered?

Efficacy of different training programs are compared in several studies but there is no consensus about which training modality is superior to other.

Konge *et al.* presented a "four step approach" to a medical simulation program (24). These four steps include: I. Theoretical preparation; II. On-site introduction to the simulation training assisted; III. Self-regulated practicing of the procedure; and IV. End of simulation training certification. They recommend that novice thoracic surgeons undergo mandatory VATS training, including simulation- based training. Training should proceed until competency has been demonstrated using valid assessments methods.

Ferguson *et al.* concluded that VATS lobectomy can be safely taught to trainee surgeons with no increase in intraoperative blood loss, morbidity, mortality or postoperative stay, but increase in operating time (25). They observed an increase in experience during the development and establishment of a VATS lobectomy program and they recommend that training programs should be coordinated at a national level to aggregate experience. Wan *et al.* demonstrated that VATS lobectomy can be taught to trainees supervised by experienced surgeons (26). In a prospective study they compared the results of VATS lung resection between experienced thoracic surgeon and surgical trainees under supervision. One hundred eleven patients with clinical stage I and II lung cancer underwent different lung resections in four years. Fifty-one of the procedures were performed by experienced consultant and 60 by trainees under supervision. One patient in the consultant group and 3 in the trainees' group were converted to open surgery due to bleeding from the pulmonary artery. The trainees spent more time in the operating room compared to experienced VATS surgeons, but there were no significant differences in intraoperative or post-operative complications and outcomes.

Reed *et al.* concluded that stepwise plan for introduction of a VATS lobectomy training program would facilitate safe learning of the technique (27). They performed 202 lobectomies in a four years period, in which 97 procedures were performed by thoracotomy and 105 were performed thoracoscopic. The number of thoracoscopic procedure increased from 18% in the first quartile to 82% in fourth quartile. This shows that VATS can be achieved safely if a stepwise transition is evoked. Sandri *et al.* described VATS lobectomy program from a trainee perspective (28). They identified three distinct issues; I. Stepwise approach to VATS lobectomy and standardization of teaching; starting with holding camera and under supervision making the ports to pulmonary ligament dissection and hilum exposure. Then advancing once experience is gained, and the trainee is sufficiently confident the next step will include vessels and bronchus dissection, gradually lobectomy and lastly lymphadenectomy. II. Off-theatre independent training; such as reviewing videos, black boxes and virtual reality simulations. III. Evaluation and certification; they suggest that as an end point to any educational program; assessment of competence and certification should be taken under consideration. Does the previous surgical experience effect the learning curve?

The new thoracic surgeons will not have the ability to start their career with thoracotomy, because of less procedures are performed by thoracotomy. Bille *et al.* and Konge *et al.* found that the number of open procedures did not impact intraoperative nor post-operative outcomes (6,29). The question is, how long does it take for a novice surgeon to learn and master VATS lobectomy compared to an experienced surgeon. Ra *et al.* examined 38 pulmonary lobectomies performed by a single surgeon without VATS lobectomy experience (30). The surgeon performed 100 lobectomies via conventional thoracotomy. They concluded that, it takes six months for a surgeon without experience to reliably perform VATS lobectomy. Out of 38 lobectomies 14 lobectomies were by VATS, 14 lobectomies by thoracotomy and 10 were converted to open thoracotomy. They had a high conversion rate, but the number of VATS lobectomy increased by time.

Conclusions

We have reviewed the recent literature on VATS lobectomy. Several studies show that there is a need for a structured training program to achieve precision. We are moving from an apprenticeship model based on a fixed time or a certain number of procedures to competency-based learning including simulation-based training. We suggest that all thoracic trainees should pass four phases consisting of theory, simulation, supervised clinical training, and independent clinical practice. Each phase should be completed with certification. (I) Theoretical phase; Reading books, articles, attending conferences, and completing multiple choice questions. (II) Off theatre preparatory phase; Starting with virtual reality simulation to learn the basic skills followed by dry and wet lab to get familiar with the real instruments and the feeling of real tissue. (III) In theatre preparatory phase; Stepwise learning, where the trainee starts with placing ports, performing minor VATS procedures; such as wedge resections, pleura biopsies etc. Once sufficient experience is gained and the trainee performance is consistent, VATS lobectomy procedures can be performed under supervision of a VATS expert until the trainee demonstrates skills and outcomes required for competency and then proficiency. (IV) Independent practice; we suggest that every end point of any educational program, evaluation, assessment of competence, should be completed with certification. It is important to continuously monitor per-operative and post-operative results and video records of each performance can be considered for evaluation.

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Footnote

Conflicts of Interest: RH Petersen: speaker fee from Medtronic, other authors have no conflicts of interest to declare.

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