Virtual simulation and learning new skills in video-assisted thoracic surgery

Benedetta Bedetti[1], Luca Bertolaccini[2], Davide Patrini[3], Joachim Schmidt[1], Marco Scarci[4]

[1]Department of Thoracic Surgery, Malteser Hospital, Bonn, Germany; [2]Department of Thoracic Surgery, Maggiore Teaching Hospital, Bologna, Italy; [3]Department of Thoracic Surgery, University College of London Hospital, London, UK; [4]Department of Thoracic Surgery, Ospedale San Gerardo, Monza, Italy

Contributions: (I) Conception and design: B Bedetti, L Bertolaccini; (II) Administrative support: D Patrini; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: M Scarci, B Bedetti, L Bertolaccini; (V) Data analysis and interpretation: J Schmidt, B Bedetti, L Bertolaccini; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Dr. Benedetta Bedetti. Department of Thoracic Surgery, Malteser Hospital, Bonn 53123, Germany.
Email: benedetta.bedetti@gmail.com.

Background: The effectiveness of training video-assisted thoracic surgery (VATS) resident surgeons using virtual reality (VR) simulation is stated in many studies, however its use is still not established in the normal practice. The purpose of this study is to create a VR curriculum to offer an evidence-based approach for VATS training programs.

Methods: Skills were evaluated with two tests: Objective Structured Assessment of Technical Skill (OSATS) and Global Operative Assessment of Thoracoscopic Skills (GOATS). Surgeons were evaluated for cognitive workload according to National Aeronautics Space Administration-Task Load Index (NASA-TLX). Subjects were stratified into two groups: trainees and consultants. Differences in performance between groups were analyzed using the Kruskal-Wallis test for nonparametric data.

Results: In total 20 voluntaries completed all tasks (trainees =12, consultant =8). Comparisons between trainee and consultant groups showed similar results in all tests on P values. OSATS and GOATS performance of both groups were similar without skills differences regarding experience. Median scores of experienced surgeons were taken as benchmark levels. Comparison of the novices' scores with benchmark levels showed that all were able to achieve the set criteria. The Kiviat diagram of the NASA-TLX cognitive workload assessment proved a greater mental and physical demand in the trainees. Nevertheless, these variations between groups were not significantly different.

Conclusions: VR training can shorten the learning curve, even if is not designed to replace the experience gained in the operating theatre. A VATS training curriculum with VR assessment allows trainees to get acquainted, train and learn the VATS lobectomy technique. This study supports clearly the inclusion of VR simulation into surgical training programs.

Keywords: Simulation training; video-assisted thoracic surgery lobectomy (VATS lobectomy); surgical simulation

Received: 13 June 2018; Accepted: 06 August 2018; Published: 29 August 2018.
doi: 10.21037/vats.2018.08.03
View this article at: http://dx.doi.org/10.21037/vats.2018.08.03

Introduction

Traditionally, thoracic surgery operations have been performed by thoracotomy. Over the last decade, video-assisted thoracic surgery (VATS) has changed the treatment of patients with lung diseases, in particular, patients with lung cancer (1). In many cases, in fact, it is possible to perform oncologic therapeutic procedures like lobectomies by VATS, even in the case of extensive disease (2). Multiple or single port can perform the VATS approach.

Figure 1 Virtual reality (VR) simulator of a right video-assisted thoracic surgery (VATS) upper lobectomy (11).
Available online: http://www.asvide.com/article/view/26669

The adoption of this technique has proven to give better results, providing a faster postoperative recovery, less pain and fewer complications (3,4). Therefore, the number of patients operated by VATS is rapidly increasing, along with the need for proper training for surgeons in this technique. The effectiveness of training VATS resident surgeons using virtual reality (VR) simulators is stated in many studies, however its use is still not established in the normal practice (5). Useful VR simulators can integrate 3-dimensional (3D) imaging, have customizable instrumentation and should expose trainees to many anatomic variations to reduce the need for continuous one-on-one instructor observation (6,7). The purpose of this study is to create a VR curriculum to offer an evidence-based approach for VATS training programs.

Methods

Each participant has been given time with an experienced operator to familiarize with the simulator before starting the assignments. To begin with, every task was demonstrated through the experienced surgeon and the participants had the chance to ask questions. No assistance has been given during hands-on training. Data for each performed assignment has been registered instantly and objectively by the simulator. Data include many information, like the time taken to execute the task, the economy of movement and error scores. The simulator software recorded the data. Basic skills were evaluated with two tests. The Objective Structured Assessment of Technical Skill (OSATS) developed two scores: an operation-specific checklist and a detailed global rating scale. In this assessment, the checklists have been assessed as simply "done correctly or not", and the global performance level will be a 5-point, anchored Likert scale (*Table S1*) (8). The other test was the Global Operative Assessment of Thoracoscopic Skills (GOATS) derived from Global Operative Assessment of Laparoscopic Skills, used to evaluate the performance of laparoscopic surgeons. This was based on the concept that the performance can be assessed in several categories (called domains) such as depth perception, bimanual dexterity, efficiency, tissue handling, autonomy, and level of difficulty. Each area was scored from 1 to 5 using a global rating scale and a task-specific checklist. This method constructed validity for the assessment of surgeons' performance of the entire VATS procedure rather than for just a few steps (*Table S2*) (9). On completing the operation, surgeons were evaluated for the cognitive workload according to the National Aeronautics Space Administration-Task Load Index (NASA-TLX), a widely recognized tool for self-reporting workload perception. The cognitive workload is a hypothetical construct that represents the cost incurred by a human operator to achieve a particular level of performance. Because the definition of the cognitive workload is human centred rather than task centred, the cognitive workload is defined uniquely by the demands of an objective task: as such, it reflects multiple attributes that may have different relevance for different individuals. The NASA-TLX rating scale is a multidimensional assessment tool that allows participants to rate their cognitive workloads on six scales (*Table S3*): mental demand, physical demand, temporal demand, effort, performance and frustration during task execution (10). A comprehensive evaluation questionnaire was also requested (*Table S4*). A 3D Systems/Simbionix simulator reproducing a right upper lobectomy (Littleton, Colorado, USA) was used from the voluntaries to complete the tasks (*Figures 1-3*).

Statistical analysis

A power calculation determined the sample size. Previous data in the literature helped us predicting the difference that we would observe in laparoscopy and robotics, so we adapted this data for VATS. Using an α value of 0.05, a β value of 0.2, and a δ value of 1.5 standard deviations, the power calculation yielded a group size of 26 subjects who will be stratified by year of training and compared with data from a cohort of "skilled" surgeons. Fisher's exact test was used to compare differences in categorical variables and the Wilcoxon rank sum test for continuous variables.

Differences in performance between groups were analysed by use of the Kruskal-Wallis test for nonparametric data. The NASA-TLX consists of two parts: ratings and weights Ratings for each of the six subscales will be obtained from the subjects following the completion of a task. Weights were determined by the subjects' choices of the subscale most relevant to the workload for them from a pair of options. The heights were calculated from the tally of these options from 15 combinatorial pairs created from the six subscales. The ratings and weights will then be combined to compute a weighted average for an overall workload score.

Results

Twenty voluntaries completed all tasks (trainees =12, consultants =8). Comparisons between novice and experienced groups showed that all tests yielded similar results on P values. In particular, OSATS (*Table 1*) and GOATS (*Table 2*) performance of both groups were similar without skills differences regarding experience. The performance was similar between two groups. Median scores of consultants were taken as benchmark levels. Comparison of the trainees' scores with benchmark levels showed that all participants could accomplish the set criteria. The Kiviat diagram of the NASA-TLX cognitive workload assessment showed a greater mental and physical demand in the trainee group; in the consultant group, the stress and performance level were greater than in the trainee group (*Figure 4*). Nevertheless, these differences between groups were not significantly different (*Table 3*). Comprehensive evaluation questionnaire showed no significant differences between trainee and consultant groups (*Table 4*).

Figure 2 Haemorrhagic complication during a simulation of a right video-assisted thoracic surgery (VATS) upper lobectomy (12). Available online: http://www.asvide.com/article/view/26670

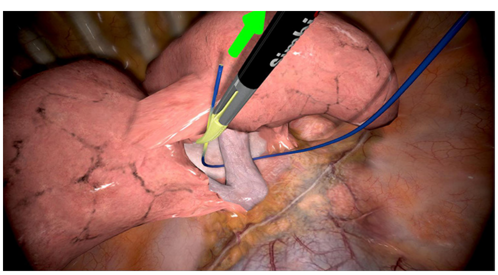

Figure 3 Guided case in a right VATS upper lobectomy performed with a virtual reality simulator. VATS, video-assisted thoracic surgery. The green arrow indicates the direction of the movement whilst circling the vessels.

Discussion

The traditional training model of modern thoracic surgical education is evolving in relation to patient safety, increasing the difficulty and heterogeneity of the surgical procedures. Recent analyses state that, by complex VATS procedures, 90 to 100 cases may be required to achieve an optimal technical level (shorter operative time and lower conversion rate (13,14). To adapt to these factors, a development of the actual teaching programs is taking place to advance cognitive and procedural abilities prior to performing in the operation theater. VR training programs are not designed as an alternative to the practice in operating theatres, but it should support a portion of the learning curve. The best approach for VR training and assessment is still debated and investigated. VR simulators have many advantages over animal models or over the traditional box trainer, including a shorter preparation time or more realistic features of the simulated VATS procedures. A VR simulator can, in fact, realistically simulate complications like bleedings or anatomical variations, which are very useful tools to speed up the learning curve for VATS procedures. Furthermore, VR simulators intended to stimulate both cognitive and psychomotor resources offer a fundamental support for practical training and evaluation. The interaction of the cognitive and psychomotor layers in simulations has been demonstrated to enhance the learning process (15). The

Table 1 Objective Structured Assessment of Technical Skill (OSATS)

Task, median [range] (n)	Trainee group (n=12)	Consultant group (n=8)	P value
Respect for tissue	4 [3–5]	4 [3–5]	NA
Time and motion	4 [2–5]	4 [4–5]	0.778
Instrument handling	4 [3–5]	5 [4–5]	0.951
Knowledge of instruments	5 [4–5]	5 [4–5]	NA
Use of assistants	4 [3–5]	4 [3–5]	NA
Flow of operation and forward planning	4 [3–5]	5 [4–5]	0.951
Knowledge of specific procedure	4 [4–5]	4 [3–5]	0.881

NA, not applicable.

Table 2 Global Operative Assessment of Thoracoscopic Skills (GOATS)

Task, median [range] (n)	Trainee group (n=12)	Consultant group (n=8)	P value
Depth perception	4 [2–5]	4 [2–5]	NA
Bimanual dexterity	4 [2–5]	5 [4–5]	0.809
Efficiency	4 [1–5]	5 [4–5]	0.527
Tissue handling	4 [2–5]	5 [4–5]	0.809
Autonomy	4 [2–5]	4 [4–5]	0.778
Exposition and division of right upper lobe vessels and bronchus	4 [3–5]	4 [4–5]	0.950
Division of right upper lobe fissures	4 [3–5]	4 [4–5]	0.950
Safe usage of vessel loop and staplers	4 [3–5]	5 [4–5]	0.951
Global autonomy	4 [3–5]	5 [4–5]	0.951
Identification of hilar structures of right upper lobe	5 [4–5]	5 [4–5]	NA
Safe dissection and division of right upper lobe vessels and bronchus	4 [4–5]	5 [4–5]	0.964
Safe right upper lobe fissures division	4 [3–5]	5 [4–5]	0.951
Accurate usage of vessel loop, staplers and other instruments	4 [4–5]	4 [1–5]	0.488
Learn how to avoid and manage potential complications	5 [4–5]	4 [4–5]	0.967

NA, not applicable.

amount of training with a VR simulator is unrestricted, and the expense for each surgery is affordable, after purchasing the simulator. Performance evaluation can be employed for appraisal and credential. This should improve patient safety, as the resident is already confident with the procedures (16). Certainly, developing a VR simulator is expensive and so it is necessary for VR trainings to be part of the surgeons' education throughout their career, so that the simulator's expenses can be compensated (17).

Many studies already published in the literature about VR simulators for laparoscopic training state the impact of this sort of training on the performance in vivo. In a randomized controlled trial of VR laparoscopy training performed from Meyerson *et al.*, the performance level of junior residents was comparable to that of intermediately experienced laparoscopists. Operation time was halved (18).

Seymour *et al.* state that the use of VR simulation significantly developed a high level of performance of trainees in the operating room during laparoscopic cholecystectomy (19). Regarding the thoracic surgery training, our study clearly supports the inclusion of VR simulation into surgical training programs and other studies in the literature support this statement. For instance, Solomon *et al.* assessed the residents on a VATS right

Table 3 National Aeronautics Space Administration-Task Load Index (NASA-TLX)

Task, mean ± standard deviation	Trainee group (n=12)	Consultant group (n=8)	P value
How mentally demanding was the task?	3.88±1.36	4.33±1.18	0.860
How physically demanding was the task?	3.75±1.30	4.36±0.88	0.726
How hurried or rushed was the pace of task?	4.38±1.49	4.11±0.74	0.685
How successful were you in accomplishing what you were asked to do?	5.13±1.36	4.67±0.94	0.854
How hard did you have to work to accomplish your level of performance?	4.38±1.22	4.08±0.95	0.906
How insecure, discouraged, stressed, or annoyed were you?	4.83±1.07	4.00±0.75	0.920

Table 4 Comprehensive evaluation questionnaire

Variables	Trainee group (n=12)	Consultant group (n=8)	P value
Face validity rating, mean ± standard deviation			
Valid training model for VATS lobectomy	9.13±1.05	9.33±0.75	0.820
Realism of procedure	8.38±1.22	7.67±2.05	0.623
Realism of camera simulation	9.00±0.87	8.33±1.03	0.872
Realism of instruments simulation	8.75±0.97	9.08±0.95	0.872
Realism of force feedback	8.13±1.54	8.00±1.53	NA
Realism of instruments freedom of movement	8.75±0.83	8.75±1.23	0.791
Realism of reaction to manipulation	8.00±1.66	8.58±1.19	0.755
Realism of pleural cavity	9.00±0.86	9.25±0.60	0.823
Hardware design	9.13±0.60	9.25±0.83	0.858
Software design	9.00±0.50	9.50±0.76	0.845
Simulator design in general	9.00±0.50	9.33±0.94	0.739
Agreement with statements, mean ± standard deviation			
Simulator is effective for procedural training	9.38±0.70	9.50±0.65	0.964
Important practice entire procedures on models	9.13±0.78	9.58±0.76	0.964
Increment of skills during training monitored	9.25±0.97	9.25±0.83	0.920
Simulator suitable for evaluation during training	9.25±0.83	9.25±0.83	NA
User-friendly learning environment	8.63±0.99	9.00±1.00	NA
Fun to use	9.63±0.48	9.58±0.49	NA
Shorten learning curves in operatory room	9.25±0.97	8.83±1.07	0.920
Reduction of the complication rates	8.63±1.40	8.50±1.50	0.950
Give starting surgeons a sense of confidence	9.50±0.50	8.83±1.28	0.545
Reduces the workload for the trainers	8.88±1.27	8.83±1.44	0.920
Reduce expenses of training after purchase	9.13±0.78	8.50±1.66	0.562

NA, not applicable; VATS, video-assisted thoracic surgery.

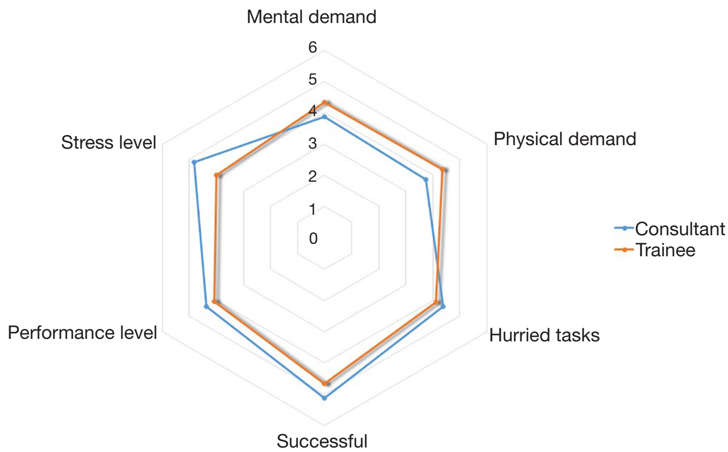

Figure 4 Kiviat diagram of the NASA-TLX. A greater mental and physical demand in was showed in the trainee group. In the consultant group, the stress and performance level were greater than in the trainee group. NASA-TLX, National Aeronautics Space Administration-Task Load Index.

upper lobectomy employing a dedicated simulator for lung resections. They validated that VR cognitive task simulation could overcome the deficiencies of existing training models (6).

Altogether, different VR simulators with various features are on the market currently and only a few of them have been officially evaluated regarding their teaching effectiveness (20). Particularly for the thoracic surgery, there is currently a predominance of models simulating bronchoscopy but a lack of simulators of thoracoscopic procedures, so the research for the perfect simulator is not ended, yet.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

References

1. Shah RD, D'Amico TA. Modern impact of video assisted thoracic surgery. J Thorac Dis 2014;6:S631-6.
2. Sekhniaidze D, Gonzalez-Rivas D. Uniportal video-assisted thoracoscopic sleeve resection. Ann Cardiothorac Surg 2016;5:145-6.
3. Vannucci F, Gonzalez-Rivas D. Is VATS lobectomy standard of care for operable non-small cell lung cancer? Lung Cancer 2016;100:114-9.
4. Bedetti B, Scarci M, Gonzalez-Rivas D. Technical steps in single port video-assisted thoracoscopic surgery lobectomy. J Vis Surg 2016;2:45.
5. Jensen K, Bjerrum F, Hansen HJ, et al. A new possibility in thoracoscopic virtual reality simulation training: development and testing of a novel virtual reality simulator for video-assisted thoracoscopic surgery lobectomy. Interact Cardiovasc Thorac Surg 2015;21:420-6.
6. Solomon B, Bizekis C, Dellis SL, et al. Simulating video-assisted thoracoscopic lobectomy: a virtual reality cognitive task simulation. J Thorac Cardiovasc Surg 2011;141:249-55.
7. Aggarwal R, Crochet P, Dias A, et al. Development of a virtual reality training curriculum for laparoscopic cholecystectomy. Br J Surg 2009;96:1086-93.
8. Reznick RK. Teaching and testing technical skills. Am J Surg 1993;165:358-61.
9. Vassiliou MC, Feldman LS, Andrew CG, et al. A global assessment tool for evaluation of intraoperative laparoscopic skills. Am J Surg 2005;190:107-13.
10. Cao A, Chintamani KK, Pandya AK, et al. NASA TLX: software for assessing subjective mental workload. Behav Res Methods 2009;41:113-7.
11. Bedetti B, Bertolaccini L, Patrini D, et al. Virtual reality (VR) simulator of a right video-assisted thoracic surgery (VATS) upper lobectomy. Asvide 2018;5:713. Available

online: http://www.asvide.com/article/view/26669
12. Bedetti B, Bertolaccini L, Patrini D, et al. Haemorrhagic complication during a simulation of a right video-assisted thoracic surgery (VATS) upper lobectomy. Asvide 2018;5:714. Available online: http://www.asvide.com/article/view/26670
13. Mazzella A, Olland A, Falcoz PE, et al. Video-assisted thoracoscopic lobectomy: which is the learning curve of an experienced consultant? J Thorac Dis 2016;8:2444-53.
14. Yang HC, Kim S, Yum S, et al. Learning curve of single-incision thoracoscopic surgery for primary spontaneous pneumothorax. Surg Endosc 2017;31:1680-7.
15. Kahol K, Vankipuram M, Smith ML. Cognitive simulators for medical education and training. J Biomed Inform 2009;42:593-604.
16. Petersen RH, Hansen HJ. Learning curve associated with VATS lobectomy. Ann Cardiothorac Surg 2012;1:47-50.
17. Aggarwal R, Mytton OT, Derbrew M, et al. Training and simulation for patient safety. Qual Saf Health Care 2010;19 Suppl 2:i34-43.
18. Meyerson SL, LoCascio F, Balderson SS, et al. An inexpensive, reproducible tissue simulator for teaching thoracoscopic lobectomy. Ann Thorac Surg 2010;89:594-7.
19. Seymour NE, Gallagher AG, Roman SA, et al. Virtual reality training improves operating room performance: results of a randomized, double-blinded study. Ann Surg 2002;236:458-63; discussion 463-4.
20. Trehan K, Kemp CD, Yang SC. Simulation in cardiothoracic surgical training: where do we stand? J Thorac Cardiovasc Surg 2014;147:18-24.e2.

doi: 10.21037/vats.2018.08.03
Cite this article as: Bedetti B, Bertolaccini L, Patrini D, Schmidt J, Scarci M. Virtual simulation and learning new skills in video-assisted thoracic surgery. Video-assist Thorac Surg 2018;3:35.

Supplementary

Table S1 Objective Structured Assessment of Technical Skill (OSATS)

Variable	Rating				
	1	2	3	4	5
Respect for tissue	Often used unnecessary force on tissue or caused damage by inappropriate use of instruments	–	Careful handling of tissue but occasionally caused inadvertent damage	–	Consistently handled tissues appropriately, with minimal damage
Time and motion	Many unnecessary moves	–	Efficient time and motion, but some unnecessary moves	–	Economy of movement and maximum efficiency
Instrument handling	Repeatedly makes tentative or awkward moves with instruments	–	Competent use of instruments, although occasionally appeared stiff or awkward	–	Fluid moves with instruments and no awkwardness
Knowledge of instruments	Frequently asked for the wrong instrument or used an inappropriate instrument	–	Knew the names of most instruments and used appropriate instrument for the task	–	Obviously familiar with the instruments required and their names
Use of assistants	Consistently placed assistants poorly or failed to use assistants	–	Good use of assistants most of the time	–	Strategically used assistant to the best advantage at all times
Flow of operation and forward planning	Frequently stopped operating or needed to discuss next move	–	Demonstrated ability for forward planning with steady progression of operative procedure	–	Obviously planned course of operation with effortless flow from one move to the next
Knowledge of specific procedure	Deficient knowledge. Needed specific instruction at most operative steps	–	Knew all important aspects of the operation	–	Demonstrated familiarity with all aspects of the operation

Global rating scale component of the intraoperative assessment tool. The descriptors shown are the “anchor” descriptors for scores 1, 3, and 5.

Table S2 Global Operative Assessment of Thoracoscopic Skills (GOATS)

Variable	Rating				
	1	2	3	4	5
Task 1	Uncertain, inefficient efforts; many tentative movements; constantly changing focus or persisting without progress	–	Slow, but planned movements are reasonably organized	–	Confident, efficient and safe conduct, maintains focus on task until it is better performed by way of an alternative approach
Task 2	Uncertain, inefficient efforts; many tentative movements; constantly changing focus or persisting without progress	–	Slow, but planned movements are reasonably organized	–	Confident, efficient and safe conduct, maintains focus on task until it is better performed by way of an alternative approach
Task n	Uncertain, inefficient efforts; many tentative movements; constantly changing focus or persisting without progress	–	Slow, but planned movements are reasonably organized	–	Confident, efficient and safe conduct, maintains focus on task until it is better performed by way of an alternative approach
Autonomy	Unable to complete entire task, even with verbal guidance	–	Able to complete task safely with moderate guidance	–	Able to complete task independently without prompting

Global rating scale component of the intraoperative assessment tool. The descriptors shown are the “anchor” descriptors for scores 1, 3, and 5.

Table S3 Subscales and items on the NASA-TLX rating scale

Scale	Description
Mental demand	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, searching, etc.)?
	Was the surgical operation easy or demanding, simple or complex?
Physical demand	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)?
	Was the surgical operation easy or demanding, slack or strenuous, restful or laborious?
Temporal demand	How much time pressure did you feel due to the rate or pace at which the surgical operation elements occurred?
	Was the pace slow and leisurely or rapid and frantic?
Performance	How successful do you think you were in accomplishing the goals of the surgical operation?
	How satisfied were you with your performance in accomplishing these goals?
Effort	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration level	How insecure, discouraged, stressed, or secure, gratified, content did you feel during the surgical operation?

NASA-TLX, National Aeronautics Space Administration-Task Load Index.

Table S4 Comprehensive evaluation questionnaire

Face validity rating (1: very bad, to 10: very good)
Simulator is a valid training model for VATS lobectomy
Realism of procedure
Realism of camera simulation
Realism of instruments simulation
Realism of force feedback
Realism of instruments freedom of movement
Realism of reaction to manipulation
Realism of pleural cavity
Hardware design
Software design
Simulator design in general
Agreement with statements (1: disagree, to 10: agree)
Simulator is effective for procedural training
It is important to practice entire procedures on virtual models
The increment of skills during training must be monitored
Simulator is suitable for evaluation during training
Simulator offers a user-friendly learning environment
Simulator is fun to use
Simulator can shorten learning curves in the OR
Simulator can reduce the complication rates
Simulator gives starting surgeons a sense of confidence
Simulator reduces the workload for those training surgeons
Simulator shall reduce expenses of training after purchase

VATS, video-assisted thoracic surgery; OR, operating room.