Peer Review File

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Reviewer A

Comment 1: Title: I suggest changing the current one to another that summarizes the results of the study. I think results are very relevant and it will be very attractive for readers.

Reply 1: Thank you for your comment. We have changed the title of the manuscript in order to summarize the positive results of our study.

Changes in text: Title: OBJECTIVE IMPROVEMENT IN DEXTERITY FOR TRAINEES UNDERGOING A VIDEO-ASSISTED THORACOSCOPIC SURGERY SIMULATION PROGRAM, A PROSPECTIVE SINGLE CENTER STUDY

Comment 2: Abstract: Key words: I would recommend increasing the number of key words to 6 (the maximum number allowed). Remember that they will help increasing the visibility of the study

Reply 2: Thank you for your comment. We have increased the number of keywords to the maximum number of six as suggested.

Changes in text: Keywords: Video-assisted thoracic surgery - surgical education – surgical training – dry laboratory – surgical simulators – dexterity.

Comment 3: Methods:

- Please, describe the variables you are going to measure (not only providing the name but also measures and how it is measured)

Reply 3: Thank you for your comment. The variables measured were the three following parameters provided by the Simball® Box: total travel distance of the instruments for a task, total time for a task and number of extreme motion movements during the task. This computer-based simulator evaluates real time metrics in order to provide an objective scoring at the end of each exercise performed, representing the overall performance of the trainee during the executed task. In our study we included the total distance covered with the instruments during each exercise which was measured in centimeters. A smaller distance needed to complete an exercise represents a more efficient and precise execution of the task. The second parameter measured was the overall time needed for the task to be completed which was measured in seconds. Again, less time represents a more efficient and precise execution of the task. The final parameter measured was the absence of periods of extreme motion. This final parameter was directly measured by the simulator which uses the four-dimension motion analysis of the working trocars/instruments and provides absence of periods of extreme motion again representing a respect of tissue and thus a controlled and safe execution of the task.

Changes in text: We have modified the text as advised (see Page 8, line 137):

Travel distance of instruments measured in centimeters is a great objective measurement of precision since a smaller distance represents a more efficient and structured execution of the task. Likewise, the total time measured in seconds also represents economy of movement and thus precision. Finally, absences of periods of extreme motion are calculated directly by the four-dimensional motion analysis of the Simball® Box and represent gestural control and respect of tissue.

<u>Comment 4</u>: Methods: Please complete the statistical analysis including more details of the analysis

Reply 4: Each participant performed all three exercises on the Simball® Box simulator three times before recording their performance, before the beginning and after the end of the training program. For each exercise, the distance in centimeters, the time in seconds and the absence of extreme motion in % were recorded for each participant. A mean +/- SD was calculated using Excel. The statistics were performed using the double-sided Student T test for each group between the pre-training and post-training performance using Excel. A p value below 0.05 was considered as significant.

Changes in text: We modified the text as advised (see page 10, line 164):

Each participant performed all three exercises on the Simball® Box simulator three times before recording their performance, before the beginning and after the end of the training program. For each exercise, the distance in cm, the time in seconds and the absence of extreme motion in % were recorded for each participant. A mean +/- SD was calculated using excel. The statistics were performed using the double-sided Student T test for each group between the pre-training and post-training performance. A p value below 0.05 was considered as significant.

<u>Comment 5</u>: Results:

The main complaint is that there are things in the section that were not anticipate in the methods section. The two first paragraphs of the results section are not commented in the methods section. This needs to be sorted out.

Reply 5: We have modified the manuscript as advised. We now describe in the method section all the points addressed in the results.

Changes in text:

See page 10, line 161:

General impressions and compliance: Throughout the course of the training sessions, we gathered feedback from trainees and supervisors regarding the quality of the two dry-lab simulators. We focused in particular on the subjective impression of the training experience provided, quality of the training program and on organizational aspects.

Our aim was to assess the strengths and limitations of each training platform and training program satisfaction.

See page 11, line 196:

General impressions: We gathered comments of the study group and supervisors on the different models.

<u>Comment 6</u>: Figure 4: Please, review the foot note of the picture because there are instruments in the picture not described in the text and vice versa.

Reply 6: Thank you for your comment. As advised, we have revised the foot note of Figure 4 now including all the instruments of the picture.

Changes in text: We have modified the text as advised (see Page 28, line 629):

Figure 4: Equipment and instruments used during the training sessions: Laparoscopic clipping reusable device, 30-degree camera with fiber optic light cable, Ethicon Echelon Flex 45mm stapler, Ethicon Echelon Endopath 45mm endoscopic linear cutter reload blue (3.6mm), thoracoscopic dissection scissors, vessel loop, Scanlan node grasping clamp, fenestrated Johann forceps, Scanlan DeBakey Forceps, thoracoscopic dissector, thoracoscopic biopsy forceps.

<u>Comment 7</u>: Discussion and references:

I suggest rewriting most of the discussion: There is a moderate body of knowledge about training in thoracic surgery and I am surprised to find references from gynecological surgery in the text. I would recommend reviewing the efforts by Massard G to create a harmonized curriculum in Europe (including simulation practices) and the multiple papers by Petersen R et al (only 1 is mentioned) about simulation, training and evaluation that are not in the text and I think they should be included and discussed.

Reply 7: Thank you for your comment. As advised, we have modified the discussion section now including the series of studies conducted by the Copenhagen group by Petersen R et al. as well as the publications by Massard G et al. for a harmonized European thoracic surgery curriculum including simulation training. The references have naturally been revised.

Changes in text: We have modified the text as advised (see Page 14, line 268):

The latest virtual reality simulator LapSim® developed by Surgical Science© (Gothenburg, Sweden) in cooperation with VATS experts at the Department of Cardiothoracic Surgery at Rigshospitalet and Copenhagen Academy for Medical Education and Simulation (CAMES), which is capable of simulation training on VATS lobectomy of all five lobes, has a total cost of € 79,000 (21).

(Page 16, line 302):

In the field of thoracic surgery and most specifically in VATS simulation surgery, a series of studies have been conducted by the Copenhagen Group which has been developing simulation modules for training and performance evaluation tools for over a decade. Jensen et al. first described a virtual reality simulator developed by Surgical Science© in cooperation with VATS experts at the Department of Cardiothoracic Surgery at Rigshospitalet, the LapSim®. The simulator was tested during the 22nd meeting of European Society of Thoracic Surgeons (ESTS) in Copenhagen, where 103 thoracic surgeons of different experience completed a lobectomy of the right upper lobe on the simulator. Although built-in metrics could not distinguish between the different levels of experience of the surgeons, this was the first commercially available virtual reality simulator for VATS lobectomy which was perceived as realistic from the participants at the time (25). On 2016 the same group achieved to correlate the level of experience of the fifty-three participating thoracic surgeons in VATS lobectomy, with their scores on the simulator, identifying seven discriminating built-in metrics. This allowed them to establish a pass/fail level and thus, validate their virtual reality simulation model as an assessment tool for evaluating competence in right upper lobe VATS lobectomy (26). Having formerly developed an assessment tool for evaluating competence in VATS lobectomy (27), they created a modified version of this assessment tool, which was used in order to evaluate performance during video-recorded lobectomies on the Surgical Science LapSim® Simulator (28).

They demonstrated a valid procedure-specific assessment tool for VATS lobectomy performance in order to further evaluate competency of trainees in this procedure. The most recent work of the group published by Haidari et al. using the same simulator which has now been upgraded in order to offer simulation training for VATS lobectomies of all five lobes, identified three measured parameters to be the most relevant in order to differentiate between the trainees' experience: procedure time, total instrument path length and blood loss (21). While blood loss is an imaginary metric provided by this specific virtual reality simulator, procedure time and total instrument path length are metrics that are objective and easily measurable while they have been shown to be shorter for experienced surgeons in previous studies (21, 29). Similarly, in our study we also evaluated instrument travel distance and time while absences of periods of extreme motion is a metric measured by the Simball® simulator which gives information about the control of movement and respect of tissue. The biggest downside of virtual reality simulators is off course the high cost. The LapSim® comes with a hefty price tag of € 79,000 which is probably a considerable investment for many institutions (21).

(See Page 20, line 388):

The steep increase in high-technology expertise and skill which are necessary for a modern practice of thoracic surgery mandate a quick adaptation to evolving technologies and new techniques. In the last decade, thoracic surgery practice has drastically changed with a major swift over minimally invasive techniques by VATS or RATS but also with technological advances in other domains of the discipline such as extracorporeal respiratory support for lung transplant and three-dimensional modelling for segmental anatomy just to name a few. Today more than ever, the need for a standardization of the thoracic surgery curriculum is evident. In their effort to create a harmonized and standardized training curriculum for European thoracic surgeons, Massard G et al. highlight the role of simulation training in acquiring the necessary skills for numerus procedures in which a thoracic surgeon needs to be proficient (33). However, it is not defined which procedures must be trained through simulation.

In this direction Haidari and al. published a consensus of key thoracic surgeons worldwide in an effort to identify and prioritize technical procedures for simulation-based training to be integrated into the thoracic surgery curriculum based on international needs assessment. Seventeen technical procedures were included for simulation training with the top-three procedures being VATS lobectomy, segmentectomy and mediastinal lymph node dissection, indicating the frequency of performing these procedures and the potentially fatal consequences of operative complications (20).

As discussed earlier, different simulation modules exist and all come with advantages and inconveniences. It is yet to be determined which module is best suited for simulation training of a specific procedure. We have described a simulation training program for learning VATS procedures using commercially available simulators, suitable for thoracic surgery residents which allows for familiarization with minimally invasive thoracic surgery in a realistic environment. Larger scale studies are necessary in order to validate such programs which could then be included in thoracic surgery training curricula.

Reviewer B

Comment 1: English is accurate

Reply 1: Thank you for your comment.

Changes in text: None.

Comment 2: Study design is not clear. Is the study a before/after study (retrospective design) or a prospective study (with registration prior to the study beginning)? Please add clarification.

Reply 2: This study was a prospective study with registration of the participants upfront as well as of the medical students. However, given it was not performed on patients and the small number of participants in our division, we did not register the study in the clinical trial gov website.

Changes in text: We have modified the text as advised (see page 8, line 116):

We prospectively included seven residents from our division (training group) and five medical students (control group) with no experience with VATS to our simulation training program. The training group had to undergo objective performance assessment on the Surgical Science Simball® Box before the beginning and after the end of our 6-month training program. The control group underwent the same evaluation on the Simball® Box at 0 and 6 months but did not participate to the training program.

Comment 3: Not every reader is accommodated to the training program of trainees (intern, resident, registrar, fellow) in Switzerland. Because there are several differences between countries regarding the curriculum of surgeons, I suggest to closely detail the curriculum of an intern/resident/registrar/fellow/consultant in the Switzerland department, in term of years for each period. Indeed, curriculum may differ from 1 to 6 years and more between countries across Europe. A figure with a timeline would be of interest.

Reply 3: Thank you for your comment. Thoracic surgery training program in Switzerland has recently been modified and now is a distinct discipline no longer requiring a board certification of general surgery as it used to be. Training for thoracic surgery in Switzerland can vary greatly between trainees as each individual is responsible to complete the curriculum's requirements without a predefined timeline. In addition, an intervention logbook has to be completed before the candidate can apply for specialty board examination and certification. Internship in a thoracic surgery department can also be part of another discipline (surgical or even medical) where the trainee choses thoracic surgery as their optional rotation. This results in a very heterogeneous group of residents/interns in most of surgical departments. Finally, the acquisition of board certification in thoracic surgery does not necessarily guarantee an attending surgeon's position since the candidate is dependent on open positions.

Currently, there are three different training positions with varying years of experience which can be resumed as follows:

Intern/resident position: no board certification with a surgical experience ranging from 0 to 6 years.

Registrar/Fellow position with no board certification: this position generally starts 4 to 6 years after the initiation of the residency and lasts 2 to 4 years with a privileged exposure to anatomical resections.

Registrar/Fellow position with a board certification. Lasts 2 to 3 years and is generally a period to increase experience before starting a staff position.

Rather than adding a figure, we have described these elements in the text (see also changes for comment 4).

Changes in text: Please see changes in text for comment 4 also addressing comment 3.

Comment 4: Also, I recommend to develop in the discussion, the role of a trainee at each level of training (intern/resident/registrar/fellow) in a conventional procedure such as lobectomy. In some countries, residents already perform several steps (and sometimes all steps) of a lobectomy. In other countries, those steps are only accessible to fellow/consultant status. Addition of their practice in the timeline suggested in comment 2 may be of interest.

Reply 4: Thank you for your comment. Generally speaking, lobectomies are performed by registrar/fellows (with or without board certification) or by attending surgeons in our institution. Residents/interns most commonly perform less complex VATS procedures such as pleurodesis and non-anatomical lung resections or parts of the dissection such as the vein and the bronchus.

Changes in text: We have modified the text as advised (see page 12, line 224):

Thoracic surgery training in Switzerland has recently become specific with no board certification in general surgery. The duration of training until board certification of thoracic surgery can vary between 6 and 10 years. Each trainee is responsible to complete the curriculum requirements before being able to undergo board examination and certification. Besides the minimum duration of training that each candidate has to complete (2 years of general surgery, 0.5 years of intensive medicine 3.5 years of thoracic surgery) there are also other requirements necessary in order to be eligible for board examination. Several courses (general surgery examination, radio-protection) and mandatory training courses such as the advanced trauma life support and others have to be successfully completed. The participation to a minimum of 3 annual thoracic surgery society meetings as well as a peer-reviewed publication as a first author are also mandatory. Finally, a logbook of more than 500 thoracic surgery interventions has to be completed.

Depending on years of experience, a resident can be promoted to a registrar/fellow position before their board examination. Generally speaking, this promotion occurs after 4 years of experience and is generally seen as a privileged access as operator for anatomical lung resections. Similarly, to other surgical disciplines, in a thoracic surgery department, the registrar/fellow has a more prioritized access to the operating room and tends to perform the majority of the cases depending on their skills and experience. During a lobectomy, residents will typically perform the incisions and closure of wounds, part of the pleural and vein dissection and assist the rest of the case. The pulmonary resection will be performed, if possible, by the registrar/fellow, under the supervision of the attending surgeon. Less complex VATS interventions such as bullae resection, pleurodesis and non-anatomical pulmonary resections will be typically performed by residents under the supervision of the registrar/fellow or / and the attending surgeon. Due to this organization, the transition from resident to registrar/fellow operator requires assistance such as with a simulation training program. Such a program can help residents overcome certain technical difficulties in a relaxed and safe environment.

We created a VATS simulation curriculum which allowed practice of a number of possible exercises in VATS, starting from camera use and hilum exposure to more complex procedures such as wedge resections and lobectomies.

Comment 5: Study is lacking detailed feedback on residents who followed this program. Did they find this useful? Did they felt that this program was accurately preparing them to perform VATS lobectomy? Only “satisfaction” and “adherence” were reported, without going into details.

Reply 5: Thank you for your comment. The seven residents who participated to the simulation training program reported great satisfaction and found it useful in order to familiarize themselves with VATS setup and instruments but also in order to acquire technical skills that is sometimes difficult in the operating room. The aim of the program was not to prepare novice thoracic surgery residents to perform a VATS lobectomy but rather familiarize them with VATS procedures, the anatomy of the human lung, instrumentation and its proper use through simulation of more or less complex exercises all the way up to a lobectomy. In addition, we wanted to test the feasibility of integration of such a program in the Department’s and residents’ day-to-day reality.

Changes in text: None.

Comment 6: Study program trained students on dry-lab VATS lobectomy program. However, study main judgment criteria were a dexterity test. Are the authors confident in the fact that dexterity is the key factor to determine preparedness to completion of a lobectomy, which constitutes a complex succession of steps and not just a dexterity driven task? Please comment on that.

Reply 6: Thank you for your comment. Our VATS simulation program included training on different exercises aiming to train specific tasks and included camera use and familiarization with the 30-degree optic, lung manipulation for anterior/posterior hilum exposure, non-anatomical lung resections, vessel dissection and stapling procedures and lobectomies. The training program was evaluated through objective assessment using dexterity parameters provided by the Simball® Simulator. Additionally, to these parameters, the steps to perform a lobectomy where also learnt: i.e., the anterior approach of the right upper lobe involving the vein first, the artery and the bronchus last. While these are important parameters, we did not record them for this study. The objective was to assess the impact of this VATS simulation training program on the dexterity of the participants as well as the overall satisfaction and feasibility of integrating such programs in the department's weekly activities.

Changes in text: None.

Comment 7: Moreover, why did the authors decided to evaluate residents on the Simball® (dexterity assessment) and not on a lobectomy model (sputnik or crabtree). One could argue that evaluation on 1) lobectomy model or 2) real-case procedure (or step of procedure), would be more accurate to extrapolate to current practice.

Reply 7: Thank you for your comment. The Simball® was chosen for its standardized exercises and possibility of a truly objective assessment of dexterity. An evaluation of participants on a lobectomy model such as the Stupnik or Crabtree would have the risk of bias and of course subjectivity from the evaluating attending surgeon. One could also argue that for instance, the same lobectomy procedure evaluated by two different surgeons could result in different scoring. Given the small number of participants as well as the direct, precise and reproducible assessment provided by the Simball® simulator on the standardized exercises selected, we believe having chosen a valid tool in order to assess our program's impact on dexterity of the participants.

Changes in text: None.

Comment 8: I don't agree with the first sentence of the discussion: "To our knowledge, this is the first study which attempts to evaluate in a prospective and objective manner the impact of a dry-lab VATS simulation training program on the dexterity of thoracic surgery residents." Bjurström JM et al. studied training through simulation for a VATS procedure (although it was not lobectomy but wedge resection in the studied you discussed on the ref #25 "Simulation-based training for thoracoscopy. Simul Healthc. 2013 Oct;8(5):317–23."

Reply 8: Thank you for your comment. We agree that many prior VATS procedure training programs have been tested. We believe that the originality of our study lies in the objective assessment of the dexterity performance using the Simball® Box. The field of simulation in training is extremely active and we believe more and more studies with various interests will be published in the coming years.

Changes in text: We have modified the text as advised (see page 11, line 199)

In this prospective study, we evaluated the objective impact of a dry-lab VATS simulation training program on the dexterity of thoracic surgery residents.

Comment 9: I don't see the interest of a comparison between a 1st year resident with dexterity training versus a last year resident without training. What conclusion should be taken considering the assessment of different experience groups with different training?

Reply 9: Thank you for your comment. In our study we compared first-year thoracic surgery residents with last-year medical students (last year before entering residency). In that extent, we thought to have compared two very similar groups in the sense that first-year residents of any surgical specialty have very little or no experience with minimal invasive surgery. Similarly, last-year medical students who are basically one year behind first-year residents, also have very little experience in that field. Since our training program was organized in weekly sessions, residents who work daily in the department were the perfect candidates for this training while medical students undergo rotations on different departments and hospitals around the country and their presence during the sessions would be hard to ensure.

Changes in text: None.

Comment 10: Regarding training of trainees in VATS lobectomy, I think that this reference should be discussed in my humble opinion. Petersen RH et al. Eur J Cardiothorac Surg. 2010 Mar;37(3):516-20. doi: 10.1016/j.ejcts.2009.09.012.

Reply 10: Thank you for your comment. As advised, we have discussed the proposed study, Petersen RH et al. Eur J Cardiothorac Surg. 2010 Mar;37(3):516-20. doi: 10.1016/j.ejcts.2009.09.012.

Changes in text: We have modified the text as advised (see page 18, line 355):

In 2009, Petersen et al. reported their experience on introducing VATS lobectomy to a training consultant. They found that introducing the procedure to a trainee in a high-volume center under supervision by an experienced surgeon and upon careful selection of patients, results in similar surgical outcomes and complication rates with those of an experienced VATS surgeon. Only operation time was found to be significantly longer for the training surgeon (32). However, the training surgeon in this study was an experienced surgeon in open procedures, had performed more than 200 minor VATS procedures and had assisted more than 50 VATS lobectomies. This is rarely the case with trainees nowadays who are exposed very quickly to minimally invasive surgery without former experience in open or minimal invasive surgery. The authors concluded that simulation training in VATS lobectomy would play an important role in the future in lowering the initial steep learning curve of this high-risk procedure.

Reviewer C

<u>Comment 1</u>: There have been evaluation methods such as OSATS and GOALS. How about adding those evaluations as well? Although the authors' method seems to be more objective.

Reply 1: Thank you for your comment. Indeed, both the Objective Structured Assessment of Technical Skills (OSATS) and The Global Operative Assessment of Laparoscopic Skills (GOALS) are validated assessment tools that assess the technical competency in a particular technique. However, both of these tools rely on a subjective evaluation from experienced surgeons. We opted for a less complex but at the same time truly objective evaluation of the participants' technical skill. We decided to devote the available time of the board-certified thoracic surgeons to supervise the training sessions rather than evaluating the performance of trainees. For this we used the precise metrics of the Simball® Box which, in our opinion, was an objective evaluation of training efficacy. At this stage, it is impossible to add the OSATS and GOALS assessment as the study is over. However, we mention these potential outcomes in the discussion.

Changes in text: We have modified the text (see page 15, line 282):

Other types of assessments could be considered such as the Objective Structured Assessment of Technical Skills (OSATS) and The Global Operative Assessment of Laparoscopic Skills (GOALS) (23,24). We did not apply those but would certainly consider them for further studies as a more subjective way of evaluating the training program.

<u>Comment 2</u>: Have the 5 subjects and the responsible surgeon really done three hours of training every week, for 6 months? One month seems enough to accomplish the same results.

Reply 2: Thank you for your comment. There were seven residents participating to our VATS simulation training program. Sessions were organized weekly, were carried out in dyads of trainees and lasted 3 hours. This resulted in approximately 10 hours of training for each participant throughout the 6-month program and this time was equally divided between observational learning through assisting and active hands-on training as main operator.

Changes in text: We have modified the text (see page 9, line 154):

One 3-hour training session was carried out per week and trainees had an average of 10-hour hands on training over a period of 6 months.

Reviewer D

<u>Comment 1</u>: Thank for your manuscript as it is, as I see it, an important work for the development of training programs for minimally invasive thoracic surgery. Therefore, I recommend to accept this manuscript after minor revision.

I totally agree with the idea of more structured and planned training curricula for residents to provide a greater reliability of progress in training. As you conclude that a protocol-based simulation training-curriculum is a valuable and effective tool for education, maybe you could describe your protocol a little more in detail. What were the specific tasks? How was progress measured or assessed? Was there feedback from the supervising instructor? Did the participants had to complete one task to proceed to the next?

As your manuscript has only little data that was measured it would be good to describe your protocol more. Maybe you could even visualize it by using some kind of flow chart.

I think your study has a great value for the topic, but you have to describe your protocol better.

Reply 1: Thank you for your comment. As advised, we have now described our VATS training program in detail. Concerning measuring the satisfaction of the participants, a questionnaire would have been indeed an easy and helpful tool but unfortunately, we did not include one in our study.

Changes in text: We have added a supplementary appendix where the exact training and exercises are described.

(See page 9 line 160): Exercise description (see supplementary appendix)

The supervisor provided assistance with tips and tricks as well as feedback at the end of each session. Each training session was devoted to two trainees and the 3-hours of the sessions were equally divided between the two with roles changing between operator and assistant. Each trainee would progressively perform the exercises as described further on this section. An exercise had to be successfully completed twice according to the supervisor’s judgment before a new exercise could be initiated. When a new session began, each trainee would resume their training repeating the last exercise that they ended the previous session with. Once all the exercises of the training program had been completed by a trainee, they were left free to choose which exercises they wanted to practice for the remaining time of their training sessions. Generally speaking, upon completion of the all the exercises of the training program, trainees chose to practice on the most complex exercises such as non-anatomical lung resections, vessel dissection and stapling and lobectomies.

The exercises are detailed here below:

- Camera use

In this exercise, trainees are introduced to the 30-degree optic and its proper utilization with focus given on the importance of maintaining the operating field at the center of the image as well as keeping the horizon line stable while changing the optic's angle.

- Lung manipulation and hilum exposure

In this exercise, trainees learn ways to manipulate the lung in a gentle way respecting tissue and avoiding lesions. Both simulators (Johnson & Johnson Ethicon Stupnik® Simulator and CK Surgical Simulation Crabtree® Simulator) were used for this task. A non-grasping as well as a grasping technique for lung manipulation was demonstrated. The exercise combines the use of forceps and dissectors for lung handling, allowing an adequate exploration of the entire parenchyma as well as anterior and posterior hilum exposure.

- Non-anatomical lung resections

For this exercise, we used the 2D model of the Ethicon Stupnik VATS Simulator. Trainees learned how to perform diverse non-anatomical lung resections. This is a type of lung resection that does not take into consideration the specific location of distant veins, arteries and bronchus. Different areas of the lung insert are marked. Using the lung manipulation techniques previously acquired, trainees perform different wedge resections of the lung apex as well as the anterior and posterior portion of the inferior lobe using automatic staplers. This exercise familiarizes our trainees with the overall use of staplers including insertion, angulation and secure firing.

- Vessel dissection and stapling

In this exercise, trainees learned a systematic approach when dissecting vessels including careful grasping, dissection and vessel control with loop placement and finally stapling. Instruments used for this exercise include graspers, De Bakey endoscopic forceps, endoscopic scissors and Harmonic Ultracision as well as staplers. On the 2D model, the appropriate plane is firstly identified and then held with the De Bakey forceps. Scissors and / or Harmonic Ultracision were used to dissect the vessel away from the underlying plane. Once the vessel is sufficiently prepared, a Crawford is used in order to further liberate the vessel and a vascular loop is placed around it. After being properly angulated, the stapler is introduced through the posterior incision. Once appropriately placed, it is securely fired, stapling and transecting the vessel.

- Right and left upper-lobe anatomical resections

For this exercise, the 3D model of the Ethicon Stupnik VATS Simulator was used for a right upper lobectomy and the Crabtree 3D-printed Simulator was used for a left upper lobectomy (Figure 5). Here we described the steps of a typical right upper lobectomy that was practiced by trainees under the guidance of the educator. First, using previously acquired skills, the lung is mobilized in order to achieve an adequate exposure of the anterior hilum. Dissection is initiated at this level and the venous system is identified, allowing upper lobar vein dissection. The anatomical identification and dissection of the upper venous system constitutes a crucial step in the procedure. The upper lobar vein is completely liberated with delicate gestures in order to avoid injury to the underlying mediastinal branch of the pulmonary artery. Using a Crawford, a vascular loop is placed encircling the vessel. The stapler is then introduced through the posterior incision and placed securely on the vessel. Once in place, the loop is removed and the stapler is fired, stapling and sectioning the vein. The next step consists in dissecting the right pulmonary artery and identifying the mediastinal branch, which supplies blood to the apical and anterior segment of the upper lobe. The mediastinal artery is dissected using scissors or Harmonic Ultracision. Once the vessel is sufficiently liberated from the surrounding tissue, a loop is placed around it and using a stapler the vessel is divided. Attention is drawn to the presence of a posterior branch existing in our model, requiring delicate dissection as well as anatomical knowledge. This smaller vessel is generally clipped and then sectioned with scissors or using the Harmonic Ultracision. Afterwards, the upper lobar bronchus is identified and dissected. It is finally stapled using the parenchymal stapler entering once again from the posterior incision. The parenchymal resection is the final step of the procedure. At this point, the upper lobe is completely detached from the hilum, solely adherent to the parenchyma of the middle and lower lobe through the small and large fissure respectively. The lobe is mobilized inferiorly using Johann forceps or a Duval endoscopic grasper. The stapler is then introduced this time through the utility incision in the 4th intercostal space. It is carefully placed on the fissure with attention payed in order to preserve the middle-lobe vessels. Several firings are usually necessary in order to divide the upper and middle lobe. Finally, the large fissure is divided, allowing extraction of the right upper lobe, completing the exercise.

Reviewer E

<u>**Comment 1**</u>: The study group consisted of seven first-year thoracic surgery residents and the control group consisted of five final years (sixth-year) medical students. Despite you affirmed that both groups had no experience with VATS, laparoscopy, or surgery-simulation courses, and the performance of the two groups was not significantly different initial Simball® Box evaluation, I suggest you to explain why you did not equally divide residents and medical students in the two groups.

Reply 1: Thank you for your comment. The idea behind this separation of the two groups between residents and medical students had to do with the logistics of this project. From our perspective,

the two groups had very little or no experience with minimal invasive surgery. Medical students undergo rotations in different departments and hospitals around the country and thus it would have been very difficult to ensure their presence during the weekly training sessions. On the other hand, residents were naturally more easily available since they worked in the department and training sessions took place during their working hours. Moreover, we considered more useful to devote the training hours to residents of our department since we believed that the skills gained during the training sessions could be useful during surgeries throughout their internship in the department.

Changes in text: None.

Comment 2: I suggest mentioning the manufacturer of the simulators used (in the text and in the figure legend).

Reply 2: Thank you for your comment. As advised, we have added the manufacturer of the simulators throughout the manuscript and figure legends.

Changes in text: We have modified the text as advised. Manufacturer of simulators added throughout the manuscript and figure legends as such:

Surgical Science Simball® Box.

Johnson & Johnson Ethicon Stupnik Simulator.

CK Surgical Simulation Crabtree Simulator.

Comment 3: You should specify the number of 3-hour training sessions carried out per week.
Reply 3: Thank you for your comment. One 3-hour training session was carried out per week. We have modified the methods section in order to clarify this.

Changes in text: We have modified the text as advised (see page 9 line 154):

One 3-hour training session was carried out per week and trainees had an average of 10-hour hands on training over a period of 6 months.

Comment 4: During each training session were all the exercises to be performed? How many times could the exercises be repeated during each session? I suggest to specify this information in the material and method section.

Reply 4: Thank you for your comment. As advised, we have modified the methods section in order to specify the information requested concerning the exercises practiced during the training sessions.

Changes in text: We have added a supplementary data where the exact training and exercises are described (supplementary appendix) and (see page 9 line 160): Exercise description (see supplementary appendix)

The supervisor provided assistance with tips and tricks as well as feedback at the end of each session. Each training session was devoted to two trainees and the 3-hours of the sessions were equally divided from between the two with roles changing between operator and assistant. Each trainee would progressively perform the exercises as described earlier. An exercise had to be successfully completed twice according to the supervisor's judgment before a new exercise could be initiated. When a new session began, each trainee would resume their training repeating the last exercise that they ended the previous session with. Once all the exercises of the training program had been completed by a trainee, they were left free to choose which exercises they wanted to practice for the remaining time of their training sessions. Generally speaking, upon completion of the all the exercises of the training program, trainees chose to practice on the most complex exercises such as non-anatomical lung resections, vessel dissection and stapling and lobectomies.

<u>Comment 5</u>: I suggest to report the software used for the Statistical analysis.

Reply 5: We used Excel (Microsoft) for all statistical analysis and have specified this point in the methods section

Changes in text: We have modified the text as advised (see page 10, line 164):

Each participant performed all three exercises on the Simball® Box simulator three times before recording their performance before the training program and at the end of the training program. For each exercise, the distance in cm, the time in seconds and the absence of extreme motion in % were recorded for each participant. A mean +/- SD was calculated using excel. The statistics were performed using the double-sided Student T test for each group between the pre-training and post-training performance using excel. A p value below 0.05 was considered as significant.

<u>Comment 6</u>: In the results, I suggest to report the exact p value.

Reply 6: We thank the reviewer for his comment. We have added all exact p values.

Changes in text: We have modified the text as advised (see page 11, line 192):

We have included in the result section the exact p values.

<u>Comment 7</u>: The legend in Figure 6 does not state what the colour orange corresponds to.

Reply 7: Thank you for your comment. As advised, we have revised the figure 6 legend in order to describe the orange color.

Changes in text: We have modified the text as advised (see page 29 line 644):

0 months (white bars) and 6-months (orange bars) without simulation training.