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ORIGINAL ARTICLE

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Outcomes from the Delphi process of the Thoracic Robotic Curriculum Development Committee

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Abstract

OBJECTIVES: As the adoption of robotic procedures becomes more widespread, additional risk related to the learning curve can be expected. This article reports the results of a Delphi process to define procedures to optimize robotic training of thoracic surgeons and to promote safe performance of established robotic interventions as, for example, lung cancer and thymoma surgery.

METHODS: In June 2016, a working panel was spontaneously created by members of the European Society of Thoracic Surgeons (ESTS) and European Association for Cardio-Thoracic Surgery (EACTS) with a specialist interest in robotic thoracic surgery and/or surgical training. An e-consensus–finding exercise using the Delphi methodology was applied requiring 80% agreement to reach consensus on each question. Repeated iterations of anonymous voting continued over 3 rounds.

RESULTS: Agreement was reached on many points: a standardized robotic training curriculum for robotic thoracic surgery should be divided into clearly defined sections as a staged learning pathway; the basic robotic curriculum should include a baseline evaluation, an e-learning module, a simulation-based training (including virtual reality simulation, Dry lab and Wet lab) and a robotic theatre (bedside) observation. Advanced robotic training should include e-learning on index procedures (right upper lobe) with video demonstration, access to video library of robotic procedures, simulation training, modular console training to index procedure, transition to full-procedure training with a proctor and final evaluation of the submitted video to certified independent examiners.

CONCLUSIONS: Agreement was reached on a large number of questions to optimize and standardize training and education of thoracic surgeons in robotic activity. The production of the content of the learning material is ongoing.

Keywords: Robotic • Thoracic surgery • Training • Curriculum • Consensus

†The first two authors contributed equally.

INTRODUCTION

Robotic lobectomy for lung cancer is a safe and feasible procedure in the hands of experienced surgeons [1–5]. The incidence of severe intraoperative complications during minimally invasive surgery (MIS) is low but potentially life-threatening [6, 7]. Thus, it is critical to perform robotic procedures only after dedicated training and in centres with higher volumes [8].

Many studies have shown that surgeons who consider using robotic techniques may not need experience with laparoscopic or thoracoscopic surgery prior to robotic training. The learning process with the robotic system (Intuitive Surgical's da Vinci Sunnyvale, CA, USA), according to some authors [9], is shorter than that for laparoscopic surgery, but insufficient training can lead to a relatively high incidence of complications [8].

The advantages of robotic thoracic surgery, including increased dexterity afforded by the wrist instrument, motion scaling, tremor filtration, absence of the 'fulcrum effect', the depth perception and the magnified view, do not necessarily guarantee improved outcomes [10, 11] and the transition from traditional surgery to advanced, totally robot-assisted surgery is not immediate. Just as in the passage from open surgery to MIS, precise organizational and didactic routes must be followed. Park *et al.* [3] indicated that before implementation of robotics into clinical practice, the surgeon and operating room team should attend an intensive, 2-day certified course. Moreover, Melfi *et al.* [10] reported that to perform a safe robot-assisted surgery, it is necessary to standardize procedures and establish operative schemes. Cerfolio *et al.* [11] has described in detail the didactic routes and steps that should be followed to gain skills and proficiency in robotic major lung resection.

Binocular and 3D visualization, a restricted operative field, the handling of robotic surgical tools with a joystick, positioning of the robotic arms and its instruments and the absence of tactile feedback are important aspects that the surgeon needs to become familiar with during training. Different authors [2, 3, 10–12] have reported the need for 18–20 robot-assisted lobectomies to be performed with the 'da Vinci' apparatus for an experienced thoracic surgeon to complete the learning curve (LC). In contrast, a comparative study by Pardolesi *et al.* [13] on the LCs of 2 surgeons for robot-assisted thoracic surgery (RATS) and video-assisted thoracic surgery showed that the curve for RATS was characterized by 2 reductions in the duration of surgery, one after 18 cases and the second after 90 cases, and was not inferior to the one for video-assisted thoracic surgery.

The LC has been defined by Ramsay *et al.* [14] according to clinical parameters and outcome, and different objective tools can be used to measure the skills when using robotics [15, 16].

As the prevalence of robotic procedures increase with the introduction of new devices on the market, increased risk related to the LC can be expected if a defined and standardized curriculum for robotic surgeons is not created and followed.

For these reasons, different scientific societies have developed specialty-specific robotic curricula, such as the Fundamentals of Robotic Gynecology Surgery, the European Association of the Urology Robotic Training and general surgery consensus meeting [15, 17–19], built upon previous work and extensive experience from fundamentals of robotic surgery. This consensus conference brought together representatives from all of the key gynaecology societies, the Robotic Training Network and JCAHO (Joint Commission: Accreditation, Health care, Certification, www.jointcommission.com) to establish a standardized robotic surgical curriculum specific to gynaecological surgeons for development and maintenance of robotic surgical skills [18].

In thoracic surgery, few articles address the topic of robotic training, and these articles are mainly individual expert opinions [11], although different training platforms are already in place in the US and Europe, and some members of this European panel have dedicated time to mentor robotic surgery following a common and structured training programme developed during time with the da Vinci manufacturer (Intuitive Surgical, Inc.). In particular, the programme in place today is already based on e-learning, simulation model and virtual reality, followed by a dry lab with porcine and cadavers and, as the final step, proctoring of live cases starting from simple procedures followed by more complex cases. This programme represented the basis from which we started our extended work of definition and standardization of the robotic curriculum for thoracic surgeons, which, however, aimed to be shared by a large group of surgeons, independent of robot manufacturing houses and therefore usable on a larger scale.

This study reports the results of the first consensus paper among experts in the field of thoracic surgery obtained through a Delphi process to define the procedures to optimize robotic training of thoracic surgeons.

METHODS

In June 2016, we established a working panel tasked with formulating a consensus view on a curriculum for a standardized modular training in robotic thoracic surgery. Initially, a small board of 5 people from the European Society of Thoracic Surgeons (ESTS) and European Association for Cardio-Thoracic Surgery (EACTS) defined the panel inviting members of both societies with a special interest in robotic thoracic surgery and/or surgical training. The project was carried out in 4 phases (i): a literature review of current evidence for curriculum training in robotic thoracic surgery was completed; (ii) a survey was then generated and sent to panel members, which incorporated the current evidence; (iii) a Delphi process using the Internet and panel-based consensus findings was completed to agree on and formulate guidance and (iv) a standardized curriculum for robotic thoracic training was designed and approved by the committee.

An *ad hoc* advisory committee was formed, including experts in the fields of Thoracic surgery from 14 different institutions in 8 European countries. Experts were identified based on specific criteria, including having prior robust clinical experience in robotic thoracic surgery and/or publications in the field or experience in the training and education among the European scientific societies; being leaders in robotic surgery according to peers; and being identified as key opinion leaders among European organizations such as the ESTS or EACTS.

The Delphi method is a systematic communication technique as in our case, for example, based on an online survey in which consensus is reached among a group of individuals on complex problems using multiple iterations of anonymous voting. The ideal number of participants required to obtain consensus in the medical field using the Delphi methodology is unknown. Therefore, the number of experts selected was based on prior experiences in which the Delphi methodology was used and on the expected response rate (20–50% according to the literature) [20].

Among the 19 invited European robotic thoracic surgeons, 14 surgeons agreed to participate.

The literature search was started in June 2016 by the panel members. Medline/PubMed (National Library of Medicine, Bethesda, MD, USA) was searched using a combination of Medical Subject Headings (MeSH) and keywords appropriate to our topic. After repeating the search several times before the first round, the selection of the papers was done by common consent. An Internet survey (Google forms) was generated and sent to all Thoracic surgery panel members (Supplementary Material, Annex S1). An e-consensus–finding exercise using the Delphi methodology was then applied. Questions in which there was 100% consensus were removed from the next round of the survey. Repeated iterations of anonymous voting continued over 3 rounds, where an individual's vote in the next round was informed by knowledge of the entire group's results in the previous round. Using the 'Google forms' software, outcomes of the e-consensus at each round were displayed as histograms so that the result could be reflected on before selecting a response in the next round. After the 3 voting rounds, the consensus views included in the final guidance needed to reach a consensus view that represented at least 80% of the panel. At the time of the final third round, a meeting was organized, which focused on discussion of the results, including consideration of the borderline questions that had not reached an 80% consensus. Cronbach's alpha was used as a measure of consistency among the opinions of the experts, and a value of ≥0.80 was chosen as the cut-off value for determining reliable consensus. We also had discussions on the planned contributions of each participant in the writing of the article.

RESULTS

Basics of the curriculum

Concerning general characteristics and criteria of robotic thoracic surgery training, all agreed that a standardized robotic training curriculum is advantageous. Additionally, there is a unanimous agreement to have a staged learning pathway by dividing the curriculum into clearly defined sections. Basic robotic skills training should include general orientation. It has to teach the technology, how to use the robot and how to handle the 'buttonology'. Similar pathways among the subspecialty groups make a common approach for basic training preferable.

Training facility

The establishment of training centres is an important step for the development of competencies. They have to be assessed by a recognized society, such as the EACTS or ESTS in Europe or the Society of Thoracic Surgeons (STS) in the USA (Fig. 1). Accreditation should be influenced by the expertise of the trainers and related to the RATS case volume in the hospital affiliated with the training centre (Fig. 2). To guarantee a high level of training quality, more than 50 cases per year, per centre, are required (Fig. 3).

Components of the training schedule

An ideal basic training programme should include an e-learning section to learn the theory and a simulation section for the practical skills. Other specialties have already shown that the e-learning part is useful and can improve the robotic skills effectively [14, 16]. There is an agreement that each section of the e-module preferably involves questions to evaluate knowledge of the candidate. Additionally, advanced e-learning modules should be evaluated with online tests for candidate feedback and to ensure the level of training.

How to dock the patient cart, information on port placement for index procedures relevant to the specialty, information on trouble-shooting and information on patient selection and preparation for robotic surgery are considered as key elements for e-learning. Further topics that are important but not considered as a primary focus of the e-learning part are emergency management and conversion (agreement not completely reached),

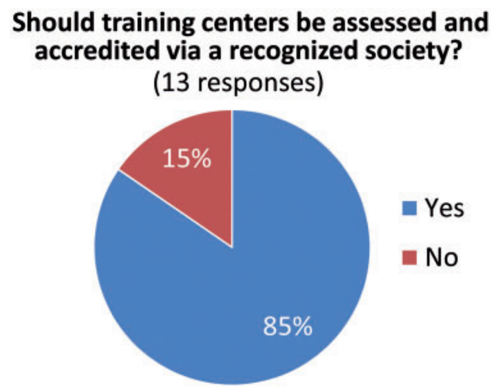

Figure 1: The majority of surgeons agreed that training centres should be accredited via a recognized scientific society.

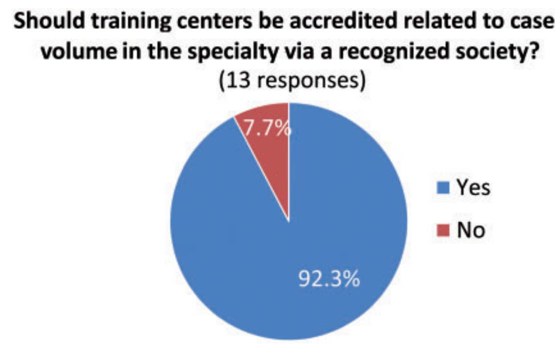

Figure 2: The group agreed that accreditation of training centres should be based on case volume.

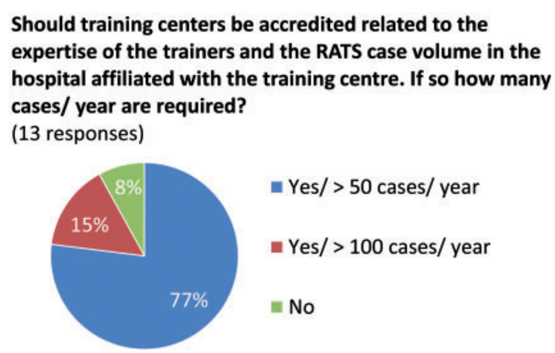

Figure 3: The majority of surgeons (<80%) agreed that the training centres should have a volume of robotic cases in the specialty >50 cases/year, another 15% considered 100 cases the minimum number every year. RATS: robot-assisted thoracic surgery.

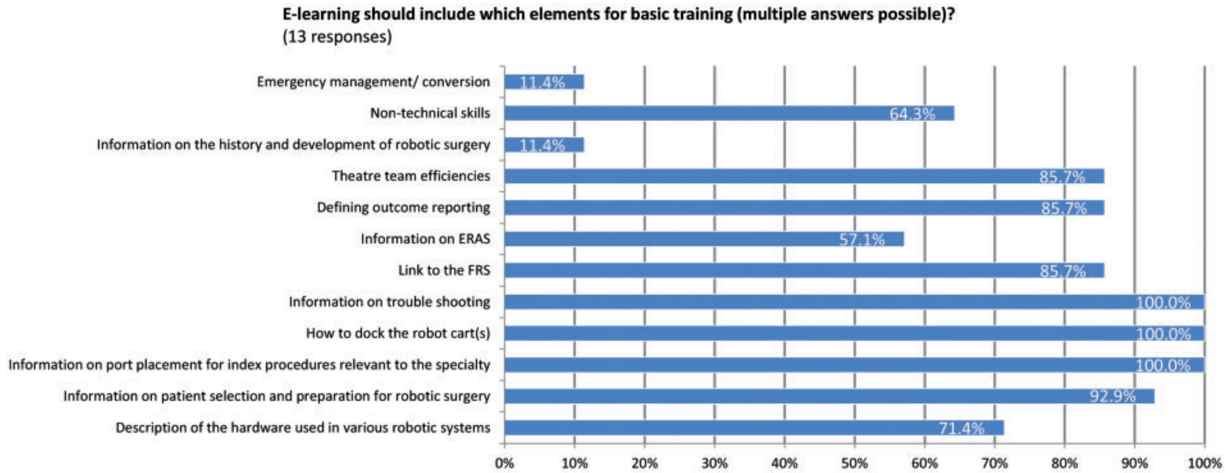

Figure 4: The elements that should be included in the e-learning module for basic training are shown, with 7 of the 12 proposed questions found 80% agreement. ERAS: enhanced recovery after surgery; FRS: fundamentals of robotic surgery.

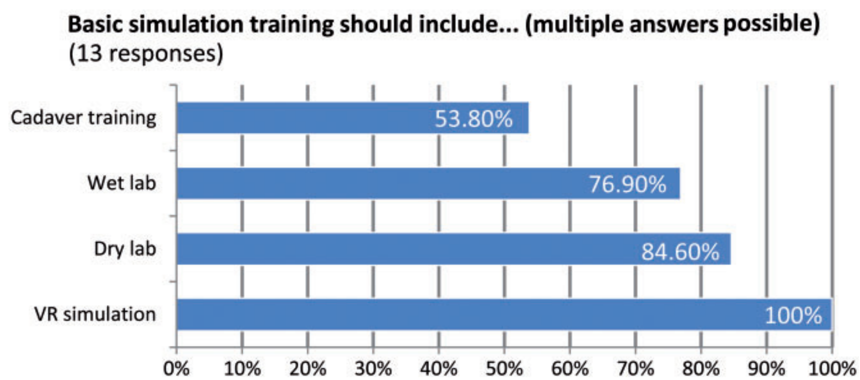

Figure 5: Basic simulation centres should include dry lab andVR. No agreement was reached for wet lab and cadaver training. VR: virtual simulation.

theatre team efficiencies, defining outcome reporting, link to the fundamentals of robotic surgery and description of the hardware used in various robotic systems. Agreement was also not reached regarding information on enhanced recovery after surgery (Fig. 4). The elements not having reached consensus for the basic part should be re-evaluated and potentially be integrated into the advanced part of the e-learning module.

According to the panel, dry lab and wet lab training is superior to cadaver training and should not be replaced by it. Additional cadaveric training does not necessarily confer specific benefits on participants (Fig. 5).

Progress evaluation

Regular baseline evaluation has to include not only a written and a knowledge-based test after the theoretical part of training but also a technical skill test (virtual reality simulation) with a review of a candidate's own videos (Fig. 6). All surgery videos, irrespective of whether they are performed for follow-up evaluation or certification should be analysed by at least 2 thoracic surgeons with expertise in the field for neutral evaluation and teaching effect purposes. Compared with the training programme in place today in which the evaluation of progression is assessed by a single proctor, according to our Delphi result, the evaluation of trainees should be as objective as possible and therefore not involve the mentor responsible for the training.

For video analysis, a scoring system consisting of subjective and objective scores would be most helpful for overall assessment. Video analysis will be given an important element of the final evaluation step for certification.

All but 1 expert considered that the required operating room observation should be case number dependent, not time dependent.

Team training and integration of non-technical skills

The majority of the committee takes the view that bedside assistance, emergency scenarios, team decision-making, docking of the robot and patient turnaround should all be part of team training (Fig. 7).

Non-technical skills can be assessed with Non-Technical Skills for Surgeons (NOTSS; www.rcsed.ac.uk/media/414560/notss-handbook-2012-no-bleeds.pdf) [16]. NOTSS is a behaviour rating system based on a skills taxonomy that allows valid and reliable observation and assessment in 4 categories of surgeons' non-technical skills: situation awareness, decision-making, communication and teamwork and leadership. With these non-technical skills, surgeons should perform surgeries safely in the operating room, and NOTSS allows the measurement of several Accreditation Council for Graduate Medical Education (ACGME) competencies, including professionalism, interpersonal and communication skills,

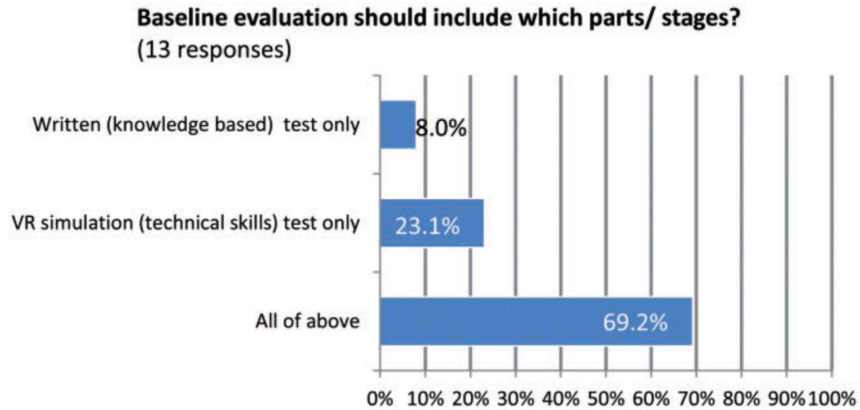

Figure 6: Baseline evaluation should include both a written test and a VR test. VR: virtual reality.

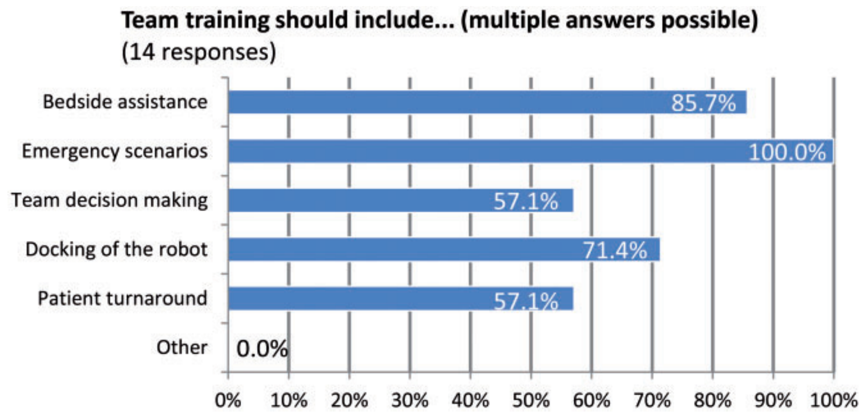

Figure 7: According to the group, bedside assistance and emergency scenario should be included in the team training.

and systems-based practice. The skills taxonomy can be used to structure training and assessment in this emerging area of surgical competence [1] (Fig. 8).

Curriculum plasticity and long-term support

An important point for the candidate proceeding with robotic procedures at their home institution is the supervision and the support of an experienced trainer or proctor. These proctorships should be executed by certified thoracic surgeons with vast experience in thoracic robotic surgery and motivation for teaching. More precise eligibility criteria were not included in the scope of our basic process.

The overall robotic curriculum training should take into account the experience of different target groups such as, for example thoracic surgery residents/fellows in accredited programmes or practising and more experienced staff surgeons. Different technical backgrounds of the participants such as open or thoracoscopic surgeons have to be respected, and particular experiences must be integrated in the curriculum.

Evaluation standards and recording systems

All experts of the committee propose that a right upper lobectomy should be the index procedure for robotic thoracic surgery. The majority favours 3 cases as the minimum number for which a trainee should be mentored and proctored by an experienced

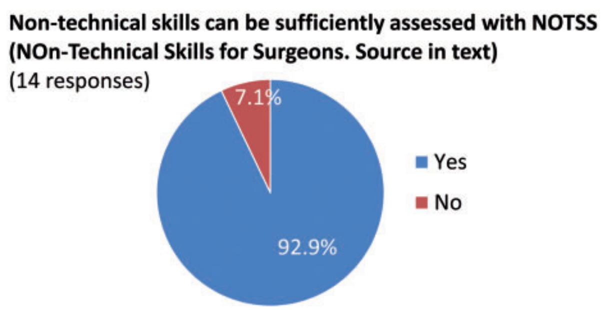

Figure 8: Non-technical skills can be assessed with NOTSS [16] (www.rcsed.ac.uk/media/414560/notss-handbook-2012-no-bleeds.pdf). NOTSS: Non-Technical Skills for Surgeons.

trainer prior to becoming an independent surgeon. Certainly this can and will vary from trainee to trainee and training or success metrics must be established.

Concerning the full-procedure technique, an evaluation of submitted videos should be performed by certified independent examiners. Considering that, a validated standardized scoring system is recommended. Ideally, it respects subjective and objective scoring elements. Using, for example the Global Evaluative Assessment of Robotic Surgery (GEARS [2]) as a template, further measurements, for example of visual cues, technical errors and events could be added to create a comprehensive and valuable evaluation tool.

For long-term quality assurance, it would be desirable that robotic trained surgeons continue to report their outcomes with standardized reporting template even after their certification. Valuable components of such a template are, for example intraoperative complications, length of stay, readmission data and other variables to be defined. It would perhaps be advantageous if this data are collected by a dedicated subset in the ESTS database.

Continuing feedback from former trainees to experts must be maintained to secure ongoing quality. Several cases, for example the 10th and 20th cases should be sent for evaluation.

The aim of a uniform and standardized training curriculum is that the trainee can benefit from a stepwise and structured learning of this specialized field in thoracic surgery with input given by different experienced thoracic robotic surgeons. The training programme must be accessible for all surgeons interested in this field. Experienced robotic-assisted thoracic surgeons are exempt from completing the advanced procedural training assessment but should have knowledge about the basic training in new robotic systems, especially if they are using a new system.

DISCUSSION

MIS provides clear advantages for patients, allowing faster recovery for return to work and earlier adjuvant treatment [21, 22]. It also allows surgeons to extend their criteria for access to surgery to patients who are more frail and who have higher numbers of comorbidities [23]. However, despite video-assisted thoracic surgery lobectomy currently being over 25 years old as a technique, the adoption rate is still <50% among surgeons in most countries of the world because of its technical challenges and also perhaps due to lack of availability of a structured training programme. Increasingly, surgeons are looking at robotic surgery as a means of performing MIS because of its ease of use, superior visualization and the significant strides in technological advancement that is making robotic surgery easier and cheaper to adopt. Indeed, it is an exciting time to be part of the robotic thoracic surgical community currently, as, in addition to the da Vinci Intuitive surgical system (Sunnyvale, CA, USA), several other robotic surgical platforms will become available to the market in the next 2–3 years including the Medtronic system (Minneapolis, MN, USA), the VERB surgical system (VERB Surgical, Mountain View, CA, USA, a subsidiary of Johnson & Johnson and Google), the Senhance surgical system by Transenterix (Morrisville, NC, USA), Medicaroid (Chuo-ku, Kobe, Japan) and the Titan Medical SPORT (Toronto, Canada).

Thus, in light of a potentially rapid increase in the number of surgeons who may be adopting a variety of robotic surgical systems, it is incumbent on us as a surgical community to ensure that we have the surgical training structures in place to safely mentor these surgeons towards a safe and independent surgical practice, building on our experiences in robotic surgery over the last decade or more. This document brings together surgeons with expertise in the practice and/or training in robotic surgery from the EACTS and the ESTS to make formal recommendations and to set the standards for such a training programme independent of the surgical system used.

This extended European group is also closely linked to the Institute of Surgical Excellence, which is a (c)(3) public non-profit organization in the USA, dedicated to improving surgical care and patient outcomes (www.surgicalexcellence.org). It has funded a successful programme and the results of our Delphi consensus process were presented at their Thoracic Surgery Robotic Consensus Conference in February 2017, where surgeons from around the world also discussed the important issue of training structures in Robotic Thoracic Surgery.

A major challenge will certainly be to obtain an homogeneous acceptance and accreditation as a centrally coordinated and supervised training curriculum created by scientific societies such as the EACTS/ESTS in Europe. Although the distinct differences in political and health systems between European countries may impede an unified training modality, every effort should be made to prevent the regulation of training activities and accreditation by manufacturers alone.

Our work and the work of this extended group will continue and intends to provide a comprehensive curriculum in Robotic Thoracic Surgery. It will provide detailed guidance in 4 domains. First, outcome measures will be defined. Twenty-five specific robotic surgery skills have been defined (including skills such as needle driving, handling, energy sources, docking and system errors) and 20 metrics have been determined to assess the skills. These include time, economy of motion, collisions and communication. Second, a curriculum will be designed including work on knowledge and also simulation. Four robotic simulation systems have already been tested for their validity in addition to a computer aided design-modelled physical training model. Third, high-stakes testing for certification is being developed to create a valid minimum standard of care for all surgeons performing robotic thoracic surgery. Finally, certification and governance must be finalized to provide comprehensive and independent assurance to our robotic community that we are mentoring all surgeons to the highest of standards and that the public can trust that a certified robotic surgeon will provide the best possible care during their procedure.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

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Conflict of interest: All members have got honorarium for expenses from Medtronic, except Patrick Dorn and Joel Dunning. Medtronic did not commission this work and did not influence the results, references and content of it in any way. Giulia Veronesi has financial relationship with Medtronic, ab medica, Johnson and Johnson, Jean-Marc Baste serves as proctor for Intuitive Surgical, Medtronic and Johnson and Johnson. Gianluca Casali received reimbursement for expenses from Intuitive Surgical; is member of different advisory boards and has delivered training for Medtronic, Johnson and Johnson, Medela and McKesson. Sasha Stamenkovic serves as proctor for Intuitive Surgical, has been part of Medtronic and Ethicon advisory boards and has been given educational

grants to teach, train or speak by the above, Medela and Baxter also. Ghada M.M. Shahin, Jan-Hendrik Egberts and Franca Melfi serve as proctor for Intuitive Surgical. All other authors declared no conflicts of interest.

REFERENCES

[1] Park BJ, Melfi F, Mussi A, Maisonneuve P, Spaggiari L, Da Silva RK *et al*. Robotic lobectomy for non-small cell lung cancer (NSCLC): long-term oncologic results. J Thorac Cardiovasc Surg 2012;143:383–9.

[2] Veronesi G, Galetta D, Maisonneuve P, Melfi F, Schmid RA, Borri A *et al*. Four-arm robotic lobectomy for the treatment of early-stage lung cancer. J Thorac Cardiovasc Surg 2010;140:19–25.

[3] Park BJ, Flores RM. Cost comparison of robotic, video-assisted thoracic surgery and thoracotomy approaches to pulmonary lobectomy. Thorac Surg Clin 2008;18:297–300, vii.

[4] Dylewski MR, Ohaeto AC, Pereira JF. Pulmonary resection using a total endoscopic robotic video-assisted approach. Semin Thorac Cardiovasc Surg 2011;23:36–42.

[5] Cerfolio RJ, Bryant AS, Skylizard L, Minnich DJ. Initial consecutive experience of completely portal robotic pulmonary resection with 4 arms. J Thorac Cardiovasc Surg 2011;142:740–6.

[6] Sandri A, Papagiannopoulos K, Milton R, Kefaloyannis E, Chaudhuri N, Poyser E *et al*. Major morbidity after video-assisted thoracic surgery lung resections: a comparison between the European Society of Thoracic Surgeons definition and the Thoracic Morbidity and Mortality system. J Thorac Dis 2015;7:1174–80.

[7] Cerfolio RJ, Bess KM, Wei B, Minnich DJ. Incidence, results, and our current intraoperative technique to control major vascular injuries during minimally invasive robotic thoracic surgery. Ann Thorac Surg 2016;102:394–9.

[8] Tchouta LN, Park HS, Boffa DJ, Blasberg JD, Detterbeck FC, Kim AW. Hospital volume and outcomes of robot-assisted lobectomies. Chest 2017;151:329–39.

[9] Hernandez JD, Bann SD, Munz Y, Moorthy K, Datta V, Martin S *et al*. Qualitative and quantitative analysis of the learning curve of a simulated surgical task on the da Vinci system. Surg Endosc 2004;18:372–8.

[10] Melfi FM, Mussi A. Robotically assisted lobectomy: learning curve and complications. Thorac Surg Clin 2008;18:289–95, vi–vii.

[11] Cerfolio RJ, Bryant AS. How to teach robotic pulmonary resection. Semin Thorac Cardiovasc Surg 2013;25:76–82.

[12] Gharagozloo F, Margolis M, Tempesta B, Strother E, Najam F. Robot-assisted lobectomy for early-stage lung cancer: report of 100 consecutive cases. Ann Thorac Surg 2009;88:380–4.

[13] Pardolesi A, Veronesi G, Solli PG, Maisonneuve P, Filippi N. Comparison of robotic with video-assisted thoracoscopic lung resection: learning, outcomes and morbidity. ESTS meeting; Lisbon 2015.

[14] Ramsay CR, Grant AM, Wallace SA, Garthwaite PH, Monk AF, Russell IT. Assessment of the learning curve in health technologies. A systematic review. Int J Technol Assess Health Care 2000;16:1095–108.

[15] Sanchez R, Rodriguez O, Rosciano J, Vegas L, Bond V, Rojas A *et al*. Robotic surgery training: construct validity of Global Evaluative Assessment of Robotic Skills (GEARS). J Robot Surg 2016;10:227–31.

[16] Non-Technical Skills for Surgeons (NOTSS). The Royal College of Surgeons of Edinburgh. https://www.rcsed.ac.uk/professional-support-development-resources/learning-resources/non-technical-skills-for-surgeons-notss. 2017 (8 January 2018, date last accessed).

[17] Goh AC, Goldfarb DW, Sander JC, Miles BJ, Dunkin BJ. Global evaluative assessment of robotic skills: validation of a clinical assessment tool to measure robotic surgical skills. J Urol 2012;187:247–52.

[18] Zevin B, Levy JS, Satava RM, Grantcharov TP. A consensus-based framework for design, validation, and implementation of simulation-based training curricula in surgery. J Am Coll Surg 2012;215:580–6 e3.

[19] Petz W, Spinoglio G, Choi GS, Parvaiz A, Santiago C, Marecik S *et al*. Structured training and competence assessment in colorectal robotic surgery. Results of a consensus experts round table. Int J Med Robot 2016;12:634–41.

[20] Tremblay C, Grantcharov T, Urquia ML, Satkunaratnam A. Assessment tool for total laparoscopic hysterectomy: a Delphi consensus survey among international experts. J Obstet Gynaecol Can 2014;36:1014–23.

[21] Bendixen M, Jorgensen OD, Kronborg C, Andersen C, Licht PB. Postoperative pain and quality of life after lobectomy via video-assisted thoracoscopic surgery or anterolateral thoracotomy for early stage lung cancer: a randomised controlled trial. Lancet Oncol 2016;17:836–44.

[22] Whitson BA, Andrade RS, Boettcher A, Bardales R, Kratzke RA, Dahlberg PS *et al*. Video-assisted thoracoscopic surgery is more favorable than thoracotomy for resection of clinical stage I non-small cell lung cancer. Ann Thorac Surg 2007;83:1965–70.

[23] Port JL, Mirza FM, Lee PC, Paul S, Stiles BM, Altorki NK. Lobectomy in octogenarians with non-small cell lung cancer: ramifications of increasing life expectancy and the benefits of minimally invasive surgery. Ann Thorac Surg 2011;92:1951–7.