EUROPEAN UROLOGY 75 (2019) 775–785

available at www.sciencedirect.com
journal homepage: www.europeanurology.com

European Association of Urology

Platinum Priority – Review – Education

Editorial by Günter Janetschek on pp. 786–787 of this issue

Utilising the Delphi Process to Develop a Proficiency-based Progression Train-the-trainer Course for Robotic Surgery Training

Justin W. Collins [a,b,*], *Jeffrey Levy* [c], *Dimitrios Stefanidis* [d], *Anthony Gallagher* [e,cc], *Mark Coleman* [f], *Tom Cecil* [g], *Anders Ericsson* [h], *Alexandre Mottrie* [b,i], *Peter Wiklund* [a], *Kamran Ahmed* [j], *Johann Pratschke* [k], *Gianluca Casali* [l], *Ahmed Ghazi* [m], *Marcos Gomez* [n], *Andrew Hung* [o], *Anne Arnold* [p], *Joel Dunning* [q], *Martin Martino* [r], *Carlos Vaz* [s], *Eric Friedman* [t], *Jean-Marc Baste* [u], *Roberto Bergamaschi* [v], *Richard Feins* [w], *David Earle* [x], *Martin Pusic* [y], *Owen Montgomery* [z], *Carla Pugh* [aa], *Richard M. Satava* [bb]

[a] Department of Molecular Medicine and Surgery (MMK), Karolinska Institutet, Stockholm, Sweden; [b] Orsi Academy, Melle, Belgium; [c] Institute for Surgical Excellence, Philadelphia, PA, USA; [d] Indiana University School of Medicine, Indianapolis, IN, USA; [e] College of Medicine and Health, University College Cork, Ireland; [f] Plymouth Hospitals NHS Trust, UK; [g] Hampshire Hospitals NHS Foundation Trust, UK; [h] Department of Psychology, Florida State University, Tallahassee, FL, USA; [i] Department of Urology, OLV, Aalst, Belgium; [j] MRC Centre for Transplantation, King's College London, UK; [k] Charite University Hospital, Berlin, Germany; [l] University Hospitals Bristol NHS Foundation Trust, UK; [m] University of Rochester Medical Center, Rochester, NY, USA; [n] Universitario Marques de Valdecilla, Spain; [o] Keck School of Medicine of USC, Los Angeles, CA, USA; [p] American College of Obstetricians and Gynecologists, Washington, DC, USA; [q] James Cook University Hospital, Middlesbrough, UK; [r] University of Southern Florida, Tampa, FL, USA; [s] Hospital da Luz, Lisbon, Portugal; [t] Aviation Safety Inspector, Federal Aviation Administration, Washington, DC, USA; [u] Department of Cardio-thoracic Surgery, Rouen University Hospital, Rouen, France; [v] Westchester Medical Center Health Network, USA; [w] Division of Cardiothoracic Surgery, University of North Carolina, Chapel Hill, NC, USA; [x] New England Hernia Center, Chelmsford, MA, USA; [y] NYU Langone Medical Center, New York, NY, USA; [z] Drexel University College of Medicine, Philadelphia, PA, USA; [aa] Department of Surgery, University of Wisconsin School of Medicine and Public Health, Madison, WI, USA; [bb] University of Washington Medical Center, Seattle, WA, USA; [cc] Faculty of Life and Health Sciences, Ulster University, UK

Article info

Article history:
Accepted December 28, 2018

Associate Editor:
James Catto

Keywords:
Robot-assisted surgery
Training
Curriculum development
Train the trainer
Surgical trainer
Surgical education

Abstract

Context: As the role of robot-assisted surgery continues to expand, development of standardised and validated training programmes is becoming increasingly important.
Objective: To provide guidance on an optimised "train-the-trainer" (TTT) structured educational programme for surgical trainers, in which delegates learn a standardised approach to training candidates in skill acquisition. We aim to describe a TTT course for robotic surgery based on the current published literature and to define the key elements within a TTT course by seeking consensus from an expert committee formed of key opinion leaders in training.
Evidence acquisition: The project was carried out in phases: a systematic review of the current evidence was conducted, a face-to-face meeting was held in Philadelphia, and then an initial survey was created based on the current literature and expert opinion and sent to the committee. Thirty-two experts in training, including clinicians, academics, and industry, contributed to the Delphi process. The Delphi process underwent three rounds of survey in total. Additions to the second- and third-round surveys were formulated based on the answers and comments from the previous rounds. Consensus opinion was defined as ≥80% agreement.

* Corresponding author. Department of Urology, Institutionssekr, Inst. för MMK, Karolinska Universitetssjukhuset, 171 76 Stockholm, Sweden. Tel. +46 764290122; Fax: +46 8 517 735 99.
E-mail address: justin.collins@ki.se (J.W. Collins).

https://doi.org/10.1016/j.eururo.2018.12.044

Evidence synthesis: There was 100% consensus that there was a need for a standardized TTT course in robotic surgery. A consensus was reached in multiple areas, including the following: (1) definitions and terminologies, (2) qualifications to attend, (3) course objectives, (4) precourse considerations, (5) requirement of e-learning, (6) theory and course content, and (7) measurement of outcomes and performance level verification. The resulting formulated curriculum showed good internal consistency among experts, with a Cronbach alpha of 0.90.

Conclusions: Using the Delphi methodology, we achieved an international consensus among experts to develop and reach content validation for a standardised TTT curriculum for robotic surgery training. This defined content lays the foundation for developing a proficiency-based progression model for trainers in robotic surgery. This TTT curriculum will require further validation.

Patient summary: As the role of robot-assisted surgery continues to expand, development of standardised and validated training programmes is becoming increasingly important. There is currently a lack of high-level evidence on how best to train trainers in robot-assisted surgery. We report a consensus view on a standardised "train-the trainer" curriculum focused on robotic surgery. It was formulated by training experts from the USA and Europe, combining current evidence for training with experts' knowledge of surgical training.

1. Introduction

Adoption of robotic systems for minimally invasive surgery has rapidly increased during the last 15 yr [1]. The da Vinci robot (Intuitive Surgical, Inc., Sunnyvale, CA, USA) was the first surgical robot approved by the U.S. Food and Drug Administration (FDA), for performing various types of procedures in urologic, gynaecologic, general, cardiothoracic, and head and neck surgery [2]. Robotic surgery facilitates minimally invasive surgery, providing immersive three-dimensional 10× magnified views of the surgical field. The surgeon's hand, wrist, and finger movements are replicated, in real time, in precise movements of miniaturised surgical instruments inside the patient's body, with automated tremor cancellation. Robotic surgery enables surgeons to perform complex minimally invasive procedures with improved visualisation, increased precision, and enhanced dexterity compared with laparoscopy [2].

A recently published study identified that over 1.75 million robotic procedures were performed in the USA across various surgical specialities between 2000 and 2013 [1]. During the study period, there were 10 624 reports of adverse events (0.6% of the total number of procedures performed). Distribution of reported adverse events was as follows: 144 deaths (1.4%), 1391 patient injuries (13.1%), and 8061 device malfunctions (75.9%) [1]. Any surgery comes with risks of complications, and the likelihood of complications increases both with the complexity of the surgery and the comorbidity of the patient [3]. Several meta-analyses and reviews have concluded that robotic surgery is overall safe and effective when compared with laparoscopic approaches [4,5]. However, with the introduction of new technologies come new risks and the need for training. These issues of adequately training surgeons in both the robotic technology and the technique are further compounded by multiple emerging robotic surgery platforms, which are being developed to improve the performance of a wider variety of surgical interventions beyond the standard minimally invasive robotic-assisted surgeries currently conducted with the da Vinci platform [6]. As the role of robot-assisted surgery continues to expand, development of standardised and validated training programmes is becoming increasingly important. Standardised surgery curricula have been shown to be beneficial in both delivering education and identifying outliers [7,8]. Curricula are a crucial step in the global standardisation of training, accreditation, and certification of surgeons for robotic surgical procedures. Several curricula are in various stages of development, and further work is needed in the development, validation, and implementation of these programmes before robotic training can be standardised [9,10].

Outside of the curricula content development, there are crucial factors directly related to trainers that can limit successful implementation of curricula, including trainers' experience as an educator, their knowledge and communication skills, and their familiarity with both curriculum content and awareness of the available simulation models to teach both technical and nontechnical skills. To improve the teaching performance of robotic-assisted surgery trainers, it is necessary to understand the important attributes of expert trainers and the optimal methods to deliver faculty development.

Optimisation of dissemination of curriculum knowledge requires the trainer to understand how adults learn relevant and defined technical skills, cognitive skills, and nontechnical skills, in addition to having skills as a trainer, including planning, developing, delivering, and evaluating robotic surgical training with formative feedback. However, there are no validated standardised training curricula for robotic trainers and no accepted assessment tool for robotic training quality and structured feedback for trainers, as have been implemented in other areas of surgical training [11]. It was therefore concluded that a train-the-trainer (TTT) consensus conference was needed. We aimed to define the key elements within a TTT programme by seeking consensus from a specialist panel formed of professionals with expertise in training from both the healthcare and the military and airline industries.

2. Evidence acquisition

The project was carried out in three phases:

1. A steering group was formed to review the literature and summarise the current evidence for TTT programmes in minimally invasive surgery.
2. A larger expert panel convened and discussed the important aspects of a TTT programme based on the current evidence. Following presentations and open discussion, a survey was created, with the input from the panel members.
3. Thirdly, panel-based consensus findings were determined using an online Delphi process to formulate guidance and provide recommendations for future research.

2.1. *Review of the literature*

The systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement [12]. In June 2017, we undertook a comprehensive computerised search using PubMed and Medline databases. We systematically searched using medical subject headings, including "robot-assisted surgery training", "robotic surgery training", "curriculum development", "train the trainer", and "proficiency-based training". The literature review was updated in January 2018.

Articles of interest included prospective studies on the impact of robotic training, robotic training curriculum development with validation, and systematic reviews on robotic training published between July 2000—when the first robotic systems received FDA approval in the USA [13]—and January 2018. Other significant studies cited in the reference list of selected papers were evaluated, as well as studies of interest published after the systematic search.

Two reviewers independently selected papers for detailed review (J.C. and D.S.) evaluating the abstract and, if necessary, the full-text manuscript. Potential discrepancies were resolved by open discussion. The electronic search yielded a total of 54 potential articles. Fig. 1 summarises the selection process. Overall, the quality of available studies was found to be low [14]. Available evidence consists largely of expert opinion, consensus statements, and small qualitative studies. No publications that focused specifically on TTT programmes for robotic-assisted surgery were identified.

2.2. *Expert panel conference meeting*

An advisory panel was formed comprising key opinion leaders with a specialist interest in robotic surgery training

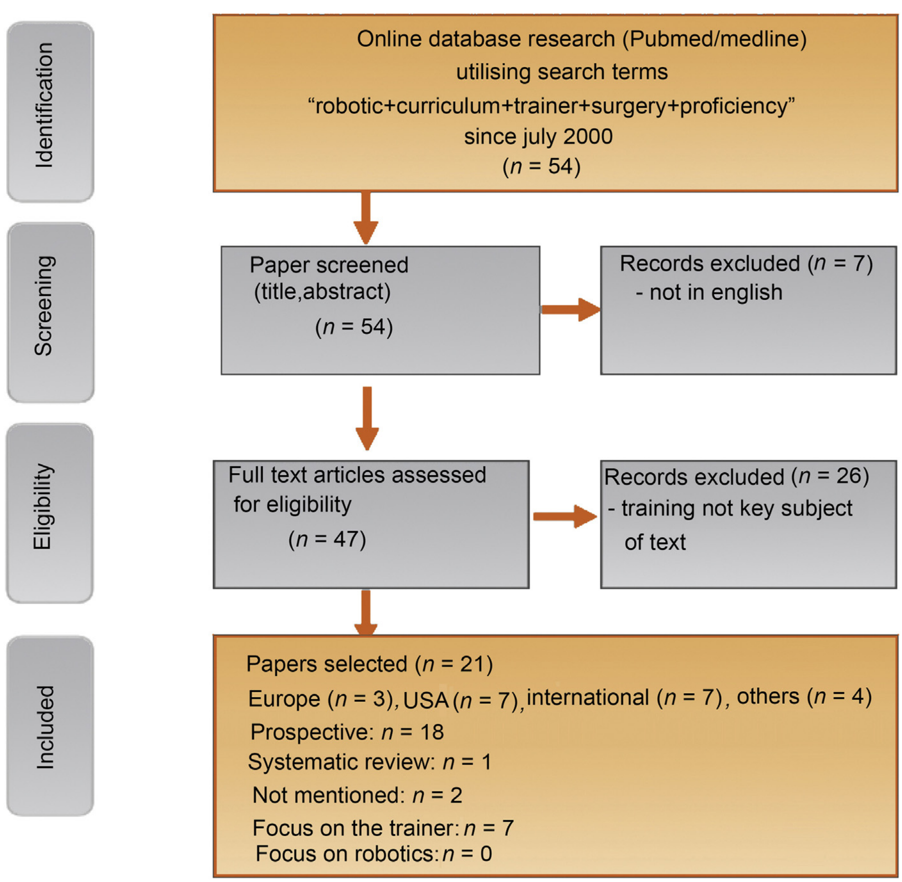

Fig. 1 – Flow chart of the selection of papers for the literature review on robotic training.

and/or setting up of TTT programmes within healthcare or other professional organisations. The panel was chaired by Drs. Jeffrey Levy, Richard Satava, Justin Collins, and Anders Ericsson. In total, 32 experts from the USA and eight European countries were brought together to develop an international standard for TTT robotic-assisted curricula. Twenty-four of them were qualified as surgeons, and the remaining eight included members of the healthcare industry, academics, or military or airline industry personnel with expertise in training. The meeting comprised presentations on the subject matter, clarifications on terminology, and reviews of the literature findings.

An overview of the various strategies for training was discussed, which included the following:

1. Education and learning theory
2. Cognitive education principles
3. Psychomotor training principles
4. Team communication principles
5. Assessment tools and scoring systems
6. Remedial education

Participants were then divided into three discussion groups:

1. Group 1: TTT course development—cognitive component
2. Group 2: TTT course development—psychomotor component
3. Group 3: Assessment tools and scoring systems

Finally, the group reconvened with a focus group discussion to summarise the three groups' conclusions, and a first draft survey was then generated with the input from the panel members.

2.3. Internet survey and Delphi process

Following the consensus conference, the Delphi process was conducted to drive consensus of the experts' opinions. An Internet survey (Google forms) was generated and sent to the 28 members of the panel that comprised the surgeons and healthcare industry experts involved in robotic training. The Supplementary material shows a full list of the survey questions. An e-consensus reaching exercise using the Delphi methodology was then applied. The Delphi method structures group communications so that the process is effective in allowing a group of individuals to deal with a complex problem. Questions in which there was ≥80% consensus were removed from the next round of the survey. Repeated iterations of anonymous voting continued over three rounds, where an individual's vote in the next round was informed by the knowledge of the entire group's results in the previous round. Outcomes of the e-consensus at each round were displayed as histograms, so the result could be reflected before selecting a response in the next round. For inclusion in the final recommendations, each survey item required to have reached group consensus (≥80% agreement) by the end of the three survey rounds. In the Delphi process, finding of a "consensus" is more relevant than the level of consensus. Levels of consensus are reported in the Supplementary material.

3. Evidence synthesis

3.1. Results

3.1.1. Formulation of guidance

We had 82% (23/28) response rate in the first round and 89% (25/28) response rate in both the second and third rounds. There was high inter-rater reliability, which was >0.80. After three rounds of Delphi surveys, a consensus was obtained in more than 60 elements in six different categories. The categories were the following:

1. Section 1: A consensus on terminology
2. Section 2: Prerequisites for TTT course selection and TTT qualifications
3. Section 3: Objectives and focus of a TTT course
4. Section 4: Precourse considerations
5. Section 5: Theory and course content
6. Section 6: Measuring outcomes

There was 100% agreement within the panel that there is a clear need for a TTT course in robotic surgery. Supplementary Tables 1–6 summarise the various elements of a TTT course that reached 80–100% agreement using the Delphi process and the levels of agreement reached.

3.1.1.1. Terminology. Uniform communication language is important for understanding roles in surgical training. If there is ambiguity in the "surgical training" terminology, it may have implications in various clinical settings, for example, understanding who has responsibility regarding clinical decision making, trainer-trainee working relationships, communication between team members, with all ultimately impacting patient care. At the meeting, we presented and discussed important terminologies related to a TTT course. A summary of these terms was circulated and agreed by the committee, and can be seen in Table 1.

The panel also identified that certain important descriptive terms currently have no clear consensus agreement. This TTT curriculum terminology was included in the Delphi process. The panel agreed that the surgeon being educated for the future role as a trainer is called a "delegate" in the TTT course and that the person giving training on a TTT course is called the "master trainer". Only after successful completion of the TTT course, the delegate is verified as a "trainer".

3.1.1.2. Prerequisites for TTT course selection and TTT qualifications. The panel reached a consensus view that TTT delegates should be experts in their fields and that there should be defined selection criteria for being accepted into a TTT course. The literature review identified descriptions of the

Table 1 – Clarifications on terminology

Term	Definition
Outcome measures	Quantifiable consequences of an action, set of actions, or procedure; also the final result that is to be measured (time, speed, accuracy, performance errors, leadership, communication skill)
Metric	Operational definition of an entity, object, location, etc.; must support an outcome measure ("no measurement, no metric")
Quantitative measures	Having numerical measures (metrics)
Qualitative measures	Having descriptive measures (distinctive attribute or characteristic of something); assessed using Likert or similar scales (eg, global rating, GEARS)
Score	Number of points, goals, etc. achieved during performance
Benchmark	A defined point of reference against which things may be compared; it is to be noted that this is not the score
Standard	The authorised exemplar of a unit of measure (performance metric: an "external" metric set by an authorised body)
Training	Act of teaching a particular skill or type of behaviour (the faculty member actively instructs)
Assessment	Evaluation of the nature, ability, or quality of performance (the faculty only observes; if feedback given, then it is considered training)
Education	Culture or development of personal knowledge—understanding, growth of character, moral and social qualities, etc.
Knowledge	The fact or state of having a correct idea or understanding of something; possession of information about something
Skill (specifically psychomotor skills)	Capability of accomplishing something with precision and certainty; practical knowledge in combination with ability, cleverness, and expertness; ability to perform a function acquired or learned with practice
Mentor	A person who acts as a guide and an adviser to another person, especially one who is less experienced; a person who offers support and guidance to another; an experienced and trusted counsellor or friend
Teacher	A person whose function is to give instruction, especially in a school
Trainer	A person who provides sustained instruction to perform particular skills, tasks, or functions
Preceptor	A person who gives instruction (in medical field, a physician or other health professional who gives practical clinical training to a medical student, nurse, etc.)
Proctor	A person responsible for supervising students in written examinations (originally at a university); an invigilator
Simulation	An artificially created or configured "learning" situation that allows for the practice or rehearsal of all or salient aspects of a procedure, including the opportunity to enact both appropriate and inappropriate learner actions (ie, errors); simulation should afford reliable and valid metric-based assessment of performance; assessments must, at a minimum, allow summative but preferably formative feedback on procedure performance proximate to task execution, particularly for metric errors [27]
Training	Sustained instruction and practice (given or received) in an art, profession, occupation, or procedure, with a view to proficiency in it; also physical preparation given or received
Practice	To exercise oneself in a skill or art in order to acquire or maintain proficiency, especially in music
Curriculum	1. Subjects comprising a program of study in a school or college 2. Content and specifications of a course of study
Competent	A person having the necessary ability, knowledge, and skill to do something successfully
Proficient	A person with a high degree of skill or expertise; an operational definition of proficient is "that it is what proficient individuals do" [45]
Expert	A person who is very knowledgeable or skilful in a particular area
Test	A procedure intended to establish the quality, performance, or reliability of something, especially before it is taken into widespread use
High-stakes test	A test that has major consequences or is the basis of a major decision (conducted by an independent, external body)
Certification	Confirmation that a certain level of achievement has been reached (awarded by an accredited authority after high-stakes test)
Proficiency-based progression	Training in a skill/task until a defined benchmark of skill is consistently met, then progressing to the next level of difficulty
Remedial education	Additional instruction provided for trainees who have been identified as requiring additional training or practice, because of poor performance

attributes of expert teachers. Hatem et al. [15] recently published a comprehensive list of the educational attributes of effective medical educators (see Table 2).

Attributes may vary with the clinical setting, and the operating room is a unique educational setting that may require a unique set of training skills [16]. The panel agreed that whilst delegates should be experts in their fields, expert surgeons are not necessarily also expert trainers. Trainees and trainers have also been shown to have different beliefs on the attributes a good surgical trainer should possess [17]. However, there is evidence that good training correlates with good patient care. In a recent analysis of expert surgical trainers, a common theme was that exceptional trainers were also excellent clinicians, dedicating their time and expertise to both the next generation of surgeons and their patients [18].

The panel concluded that important individual qualities for surgical trainers include being knowledgeable, interested, and enthusiastic; enjoying training; being a good communicator; being supportive; having time to train; and knowing when to interject to prevent harm without trying to take over. The best trainers are those who are

Table 2 – Attitudes and attributes, knowledge, and skills of competent teachers [13]

Attributes	Knowledge	Skills
Acknowledges that the goal of effective teaching is directed at effective learning and understanding.	Demonstrates awareness of and tacitly or explicitly employs basic pedagogic principles.	Communicates knowledge effectively and makes it relevant to the learner.
Advocates for education.	Displays awareness of and uses teaching techniques in line with current neuroscience and cognitive psychological findings.	Demonstrates leadership in educational settings.
Believes in a teacher's code of ethics for teaching medicine.	Is knowledgeable and up to date in one's discipline.	Demonstrates the basic skills for effective lecturing and facilitating small and large group discussions.
Demonstrates passion as a teacher.	Promotes scholarship.	Questions, listens, and responds effectively.
Demonstrates kindness in all interactions.	Understands the concept of creating a safe environment for the trainee	Establishes a learning community that values education and the process of continual learning.
Demonstrates awareness of own limitations and is not afraid to say “I don't know”.		Establishes an educational contract with learners, identifying learners' needs and clarifying the teacher's expectations.
Is accessible to learners.		Gives praise as well as critical feedback in a manner acceptable to the learner.
Manifests and stimulates curiosity.		Is a reflective, mindful teacher.
Seeks and obtains knowledge of learners.		Is able to capture and maintain attention.
Values and establishes a safe learning environment.		Is adaptable and flexible.
Values and functions as an effective role model.		Promotes critical thinking.
		Promotes self-directed learning.
		Provides timely summative evaluations.
		Uses information technology effectively.

“available” and also understand when to give progressive responsibility and autonomy to trainees [19]. Trainers need to be able to commit to a defined number of training courses per year. Recommendation for delegates for the TTT course may come from various sources: professional societies or organisations, hospital/programme directors, medical boards, and/or industry. When targeting delegates for the TTT course, selection should be linked to faculty development.

Delegates should be tested on the TTT course and assessed for proficiency on knowledge of their teaching topic as well as proficiency in running training courses. Whilst the assessment of surgical trainees has become well established in most international practices, this is not yet the case for surgical trainers. We identified two studies in the literature that have developed and provided validity evidence of a surgical trainer assessment tool [11,20]. The panel concluded that only delegates who achieve “proficiency” on the TTT course via a validated assessment tool should be verified as a “trainer”.

3.1.1.3. Objectives of a TTT course. The panel agreed that there should be clearly defined objectives for the TTT course and that the course should provide education addressing all required skills (see Fig. 2). In procedural training, there is a need to include training in the avoidance and management of common complications specific to that procedure and their relationship to technical errors.

It was recommended that the TTT course should focus on both educating the delegate to become a verified trainer and how to set up a standardised “training programme”, based on the current best practice.

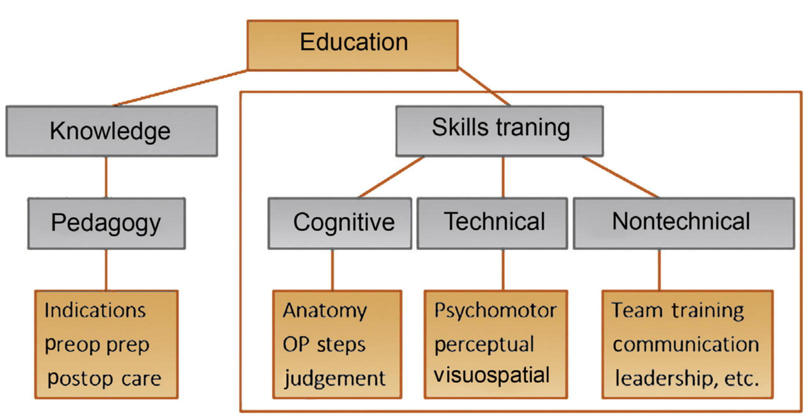

Fig. 2 – Defining the difference between knowledge and skills training. OP = operation.

Key focus points that were identified by the panel as being important for the TTT course included instruction on how to optimise guidance on defined technical skills, and training in providing feedback and debriefing following the assessment of technical skills. The panel also recognised the need for training in technical skills' rating and calibration exercises, and the importance of psychometric robustness of these technical skill assessment tools. The TTT course should provide opportunities to practice rating training skills in the operating room and laboratory/simulation setting.

Other important areas of knowledge included an understanding of the learning curve in surgery and how to "shorten" the learning curve [21,22]. There was also agreement on the importance of being aware of the impact of stress in the training environment [23] and the necessity for prioritising patient safety, during training [23]. Expectations and training goals have been shown to differ between the trainer and trainee [17]. To avoid misunderstandings, the panel recommended that the trainer should always seek agreement with the trainee regarding the goals and objectives of the course (trainee-directed learning). The panel concluded that successful TTT programme implementation would result in increased adoption of "training programmes" set up by TTT-verified trainers. Evaluating successful faculty development is the key to demonstrating values and benefits of the course [24].

3.1.1.4. Precourse considerations. The group considered what needs to be included in a "checklist" of basic requirements for setting up a TTT course. Multiple elements reached ≥80% consensus and are summarised in Table 3.

The groups' guidance for precourse e-learning modules was that it should include the following:

1. Details of the TTT course content and clearly defined objectives of the TTT course
2. List of skills to be taught
3. Definitions of terminologies
4. Defined role play tasks and aims of role play
5. Educational theory information related to the course
6. Relevant subject matter details related to future training courses, for example, a Fundamentals of Robotic Surgery (FRS) TTT course should describe the FRS
7. Procedural-based TTT courses that should describe important standardised content to be given by the trainers, for example, important anatomy, port placement, and surgical steps
8. Precourse evaluation that should include assessment of the delegate's knowledge of the course subject matter and/or technical procedure aspects to be given in the training course

There was consensus agreement within the panel that completion of e-learning related to the TTT course should be a basic requirement before attending the TTT course, and that it is important to identify the participant's gaps in knowledge of the proposed training programme that the participant will run and address them before the TTT course commences. Additionally, baseline evaluation of the delegates should be benchmarked, once enough data from TTT courses are available to formulate a benchmark. This benchmark needs to be set and quantified so that it is specific to a TTT course. The panel also recommends that it is important to set expectations at the beginning or before commencing the course, but that precourse e-learning modules should include opportunity for the delegates to provide details regarding which additional training aspects they wish to get from the TTT course.

3.1.1.5. Educational theory and practical exercises to be included in course content. The panel reached agreement on multiple areas of educational theory and course content for a standardised TTT course. Below we summarise the areas of agreement related to subject matter, exercises, feedback, and assessment tools.

Table 3 – Checklist for setting up a TTT course

Personnel	Facilities and equipment	Course content materials
A "master trainer" to run the TTT course	A meeting room with a laptop and a projector for PowerPoint presentations	Description of syllabus and timetable to send to delegates, including "basic ground rules"
Actors/students/colleagues to participate in role play scenarios	Simulation training room	E-learning modules available online
Administrative staff	Suitable simulation equipment, for example, dry and wet labs, and VR simulation and OR simulation equipment	Educational video examples of good and bad practice
A suitable number of delegates	A list of equipment required for training exercises, for example, performance-enhancing instruction exercise (throwing a ball in a bucket behind you that you cannot see; see section 3.1.1.5 for the list of exercises	Written vignette/scenarios for role play
	Standardised template slides for training content	Standardised data analysis forms/outcome metrics/ checklists
	Live video feed from the OR with potential for interaction	Team training examples with nontechnical skill training scenarios
	Standardised handouts for the delegates, including feedback forms	Group feedback task description

OR = operating room; TTT = train the trainer; VR = virtual reality.

Important subject matters to be covered in a TTT course:

1. Highlighting the importance of team contribution to training and describing the behaviours of "good" team members [25].
2. How to deal with the difficult trainee
3. Guidance on how to avoid taking over in theatre as the trainer; explanation of the "six steps" of safe mentoring [26]
4. Cognitive task analysis [27]
5. Description and explanation of "deliberate practice" [28]
6. Description of proficiency-based progression [29]
7. How to reflect and the importance of reflection [30]
8. How to debrief [31]
9. How to give formative feedback [32]
10. Task deconstruction [32]
11. Description and explanation of "performance-enhancing feedback" [33]
12. Identification of take home messages

Exercises:

1. Practical demonstrations/role play/tasks/group participation
2. Task repetition to demonstrate deliberate practice [34]
3. Example of task deconstruction, defining a specific activity to be taught, reducing the activity to the smallest component parts [31]
4. Explanation of the "six steps": (1) stop, (2) identify, (3) explain, (4) structured teaching, (5) elicit check of understanding, and (6) proceed if safe [26]
5. Proficiency-based progression exercises [35]
6. Role play exercise that describes and explains the effect of cognitive load [36]
7. Formative feedback exercise (throwing a ball in the bucket behind you with formative feedback) [36]
8. Practical training role play: role play scenarios played out with delegate interaction and assessment of trainer's performance with open discussion and feedback, combined with formative feedback exercise

3.1.1.6. Measuring outcomes with assessment tools. The panel identified that robotic surgery assessment includes technical skills, cognitive assessment, and nontechnical skills. The robustness of technical skill assessment tools is important for the continuum of training. Robotic technical skills are currently commonly assessed with Likert scale measures such as GEARS [37], whereas proficiency-based progression is based on objective metrics that often relate to the completion of defined tasks and avoidance of defined errors.

The panel reached a consensus that outcome measures need to be objectively defined for the assessment of delegate performance as trainers. For proficiency-based progression, end scenarios should be described, which give the delegate the opportunity to demonstrate proficiency in various training goals [34]. For proficiency-based progression, delegates should have the opportunity to repeat the scenario until they achieve proficiency. The panel agreed that a combination of these training assessment metrics may be optimum (see Fig. 3). Exercises to demonstrate proficiency-based progression include a video to show a student demonstrating an error, where the delegate gives feedback. If the master trainer indicates a pass or a fail score, he/she needs to be able to clarify why the individual passed or failed.

The literature review highlighted that an increasing number of objective assessment tools are specific to both robotic procedures [38,39] and individual tasks [40]. The panel agreed that a TTT course should describe which assessment tools are currently available and relevant to the training programme, and define which assessment tools are most appropriate for use in different settings. Video performance analysis can also be beneficial for instruction and feedback [41]. The panel reached a consensus that both objective feedback (structured) and reflective comment (unstructured) are useful and beneficial to learning.

At the end of the course, a postcourse evaluation test of the delegates should be compared with the precourse test

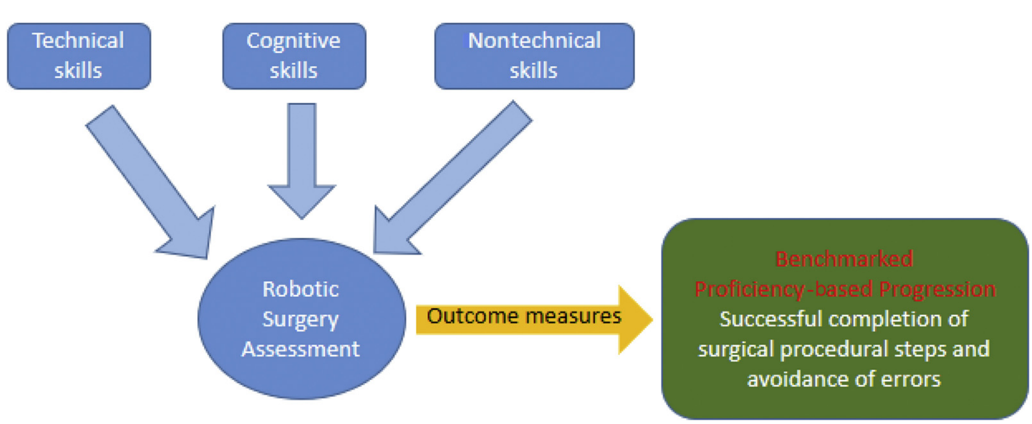

Fig. 3 – Robotic-assisted surgical skills training should include training of technical, cognitive, and nontechnical skills with reassessment until a benchmark value is reached.

and formative feedback should be given to the delegates on their performance. Delegates should also have the opportunity to comment on the various aspects of the course using a written questionnaire to evaluate both the course and the master trainer.

3.1.1.7. Verifying "trainer" competency during a TTT course. The literature review revealed that there is currently a lack of assessment tools available for robotic surgical trainer evaluation. The English National Training Programme has developed, validated, and implemented an assessment tool for laparoscopic colorectal surgery [11]. In this study, the group identified four key areas to assess the trainer in, namely, training structure, training behaviour, characteristics demonstrated during training, and demonstration of technical and nontechnical skills. The panel agreed that this area required further research.

There was agreement that training of TTT delegates should be proficiency based, with necessary skills/tasks performed until a defined benchmark is consistently met, and then the delegate progresses to the next level of difficulty [29,42].

Effectiveness of a TTT course should be evaluated using the current concepts of validity. The panel also recommended that a successful delegate, who has received verification as a faculty trainer, should be reverified in skill training and assessment every 2 yr.

3.2. Discussion

The use of robotic-assisted surgery has been increasingly adopted since its introduction in the 1990s [13]. We can also see the imminent arrival of new robotic systems in the market. Nonautomated robotic surgery where instruments are directly controlled by the surgeon was first developed in the 1990s with a so-called "master-slave system" [43]. Nonautomated robotic surgery needs the novice to be trained in both the technology and the surgical technique. Implementation of training guidelines and proctoring recommendations is necessary to protect surgeons, trainers, proctors, institutions, and, above all, patients who are operated on after the introduction of a robot-assisted surgery programme.

Halsted introduced one of the first standardised surgical training programmes[48]. The Halstedian method relied heavily on the apprenticeship model and the frequently quoted "see one, do one, teach one" approach [49]. Advantages to this approach included a strong relationship between the trainee and trainer, and the gradual increase in responsibility with skill acquisition. Disadvantages of this approach include that it is outdated in the current working hour restrictions and that there are concerns about patient safety with a "see one" approach or indeed about acquiring skills on patients [44]. Standardised and validated robotic curricula and competency-based accreditation processes are important for the future of young surgeons and robotic service implementation, since patient safety and improved surgical outcomes will drive adoption [10]. However, standardised curricula in isolation are not sufficient to ensure that all trainees receive uniform training irrespective of their training programme. Trainers also need guidance on training and to be verified as competent trainers. Additionally, the feedback loop between trainers, trainees, and credentialing can be adequately achieved only with standardised performance metrics that are consistent and reproducible.

A recent literature review of the surgical learning curve revealed that time to complete the procedure is the commonest determinant to assess an individual's learning curve in robotic surgery performance [45]. Lee et al. [46] recommended that instead of being based on a set number of completed cases, robotic surgery credentialing should involve the demonstration of proficiency and safety in executing basic robotic skills and procedural tasks. In addition, the accreditation process should be iterative to ensure accountability to the patient.

Multiple assessment tools are available for different robotic procedures. The panel reached an agreement that the ideal assessment tool is objective and proficiency based, and that patient safety and outcomes can be improved with a focus on gaining proficiency and avoiding errors. Defined benchmarking and standardised error reporting would more accurately reflect expertise levels and allow for feedback that would be more informative compared with current practices of reporting time to complete the steps of the operation.

However, we currently lack standardised outcome metrics and error reporting. Clinically relevant "benchmarking" of proficiency levels is not routinely used to determine the learning curve. Objective quantification of surgical performance requires benchmarking and objective scoring metrics to gauge performance reliably. The panel recognised that proficiency-based progression training is designed to address these requirements [47]. Proficiency-based progression is a training methodology where training in a skill/task is repeated until a defined benchmark of skill is consistently met, only then the trainee progresses to the next level of difficulty. It therefore builds on the success of the Halstedian training model, where the trainee has a gradual increase in responsibility linked to his/her levels of skill acquisition.

Identification and avoidance of errors will also help in the standardisation of objective robotic training. Development of robotic surgical systems with enhanced technologies that can identify and report adverse events and errors will also likely help reduce preventable errors in the future. The use of a video in minimally invasive surgery gives unique opportunities to teach, identify errors, and review and score surgical performance [41]. However, the panel identified that there is currently poor standardisation around the definition of errors, causes and consequences of errors, classification of outcome measures and metrics needed to evaluate errors, and training to prevent errors.

4. Conclusions

Although robotic surgery is increasingly being employed in complex surgery, few validated curricula exist for standardised training. Robotic surgery trainees require training in both technology and surgical technique. As the use of robotic surgery becomes more widespread, an agreed standard of surgeons' proficiency is needed with an understanding of how this is optimally taught.

Using the Delphi methodology, we achieved an international consensus among experts to develop and reach content validation for selecting and verifying trainers in robotic surgery. We have formulated a standardised "TTT" curriculum for robotic surgery training. This defined content lays the foundation for developing proficiency-based progression models for robotic trainers. Although this TTT curriculum will require further iterative improvement and formal demonstrated effectiveness, the value of a consensus-driven conference utilising the Delphi methodology has clearly been demonstrated.

Author contributions: Justin W. Collins had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Collins, Levy, Gallagher, Satava, Ericsson.
Acquisition of data: Collins, Levy, Stefanidis, Gallagher, Coleman, Cecil, Ericsson, Mottrie, Wiklund, Ahmed, Pratschke, Casali, Ghazi, Gomez, Hung, Arnold, Dunning, Martino, Vaz, Friedman, Baste, Bergamaschi, Feins, Earle, Pusic, Montgomery, Pugh, Satava.
Analysis and interpretation of data: Collins, Levy, Stefanidis, Gallagher, Coleman, Cecil, Ericsson, Mottrie, Wiklund, Ahmed, Satava.
Drafting of the manuscript: Collins, Stefanidis, Satava.
Critical revision of the manuscript for important intellectual content: Collins, Levy, Stefanidis, Gallagher, Coleman, Cecil, Ericsson, Mottrie, Wiklund, Ahmed, Pratschke, Casali, Ghazi, Gomez, Hung, Arnold, Dunning, Martino, Vaz, Friedman, Baste, Bergamaschi, Feins, Earle, Pusic, Montgomery, Pugh, Satava.
Statistical analysis: Collins.
Obtaining funding: Levy.
Administrative, technical, or material support: Collins, Levy, Satava.
Supervision: Satava, Gallagher.
Other: None.

Financial disclosures: Justin W. Collins certifies that all conflicts of interest, including specific financial interests and relationships and affiliations relevant to the subject matter or materials discussed in the manuscript (eg, employment/affiliation, grants or funding, consultancies, honoraria, stock ownership or options, expert testimony, royalties, or patents filed, received, or pending), are the following: Justin Collins received research grants from Intuitive Surgical and Medtronic, and consultancy fees from Medtronic.

Funding/Support and role of the sponsor: This work was supported by the Institute of Surgical Excellence, Philadelphia, PA, USA. Funding was used to cover travel and hotel expenses. No honoraria were paid to the panel of experts.

Acknowledgements: We would like to thank the Institute for Surgical Excellence and the steering committee, comprising Jeffrey Levy, Justin Collins, Anthony Gallagher, Anders Ericsson, and Richard Satava, for their organisation and for recruiting the expert panel.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.eururo.2018.12.044.

References

[1] Alemzadeh H, Raman J, Leveson N, Kalbarczyk Z, Iyer RK. Adverse events in robotic surgery: a retrospective study of 14 years of FDA data. PLoS One 2016;11:e0151470.
[2] Intuitive Surgical Inc. The da Vinci Surgical System. http://www.intuitivesurgical.com/products/davinci_surgical_system/.
[3] Maerz DA, Beck LN, Sim AJ, Gainsburg DM. Complications of robotic-assisted laparoscopic surgery distant from the surgical site. Br J Anaesth 2017;118:492–503.
[4] Novara G, Catto JW, Wilson T, et al. Systematic review and cumulative analysis of perioperative outcomes and complications after robot-assisted radical cystectomy. Eur Urol 2015;67:376–401.
[5] Tsuda S, Oleynikov D, Gould J, et al. SAGES TAVAC safety and effectiveness analysis: da Vinci® surgical system (Intuitive Surgical, Sunnyvale CA). Surg Endosc 2015;29:2873–84.
[6] Rassweiler JJ, Autorino R, Klein J, et al. Future of robotic surgery in urology. BJU Int 2017;120:822–41.
[7] Ahmed K, Khan R, Mottrie A, et al. Development of a standardised training curriculum for robotic surgery: a consensus statement from an international multidisciplinary group of experts. BJU Int 2015;116:93–101.
[8] Brunckhorst O, Volpe A, van der Poel H, Mottrie A, Ahmed K. Training, simulation, the learning curve, and how to reduce complications in urology. Eur Urol Focus 2016;2:10–8.
[9] Fisher RA, Dasgupta P, Mottrie A, et al. An over-view of robot assisted surgery curricula and the status of their validation. Int J Surg 2015;13:115–23.
[10] Volpe A, Ahmed K, Dasgupta P, et al. Pilot validation study of the European Association of Urology robotic training curriculum. Eur Urol 2015;68:292–9.
[11] Wyles SM, Miskovic D, Ni Z, et al. Development and implementation of the Structured Training Trainer Assessment Report (STTAR) in the English National Training Programme for laparoscopic colorectal surgery. Surg Endosc 2016;30:1003–993.
[12] Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred Reporting Items for Systematic Reviews and Meta-analyses: the PRISMA statement. PLoS Med 2009;6:e1000097.
[13] Leal Ghezzi T, Campos Corleta O. 30 Years of robotic surgery. World J Surg 2016;40:2550–7.
[14] GRADE Working Group. Grading quality of evidence and strength of recommendations. BMJ 2004;328:1490.
[15] Hatem CJ, Searle NS, Gunderman R, et al. The educational attributes and responsibilities of effective medical educators. Acad Med 2011;86:474–80.
[16] Dean B, Jones L, Garfjeld Roberts P, Rees J. What is known about the attributes of a successful surgical trainer?. A systematic review. J Surg Educ 2017;74:843–50.
[17] Nisar PJ, Scott HJ. Key attributes of a modern surgical trainer: perspectives from consultants and trainees in the United Kingdom. J Surg Educ 2011;68:202–8.
[18] Sutton PA, Beamish AJ, Rashid S, et al. Attributes of excellent surgical trainers: an analysis of outstanding trainers. Int J Surg 2018;52:371–5.
[19] Wojcik BM, Fong ZV, Patel MS, et al. Structured operative autonomy: an institutional approach to enhancing surgical resident education without impacting patient outcomes. J Am Coll Surg 2017;225, 713–724.e2.

[20] Dean BJF, Keeler B, Garfjeld Roberts P, Rees JL. Development of a surgical trainer assessment questionnaire. ANZ J Surg 2018;88:45–9.
[21] Abboudi H, Khan MS, Guru KA, et al. Learning curves for urological procedures: a systematic review. BJU Int 2014;114:617–29.
[22] Moreno Sierra J, Fernández Pérez C, Ortiz Oshiro E, et al. Key areas in the learning curve for robotic urological surgery: a Spanish multicentre survey. Urol Int 2011;87:64–9.
[23] Georgiou K, Larentzakis A, Papavassiliou AG. Surgeons' and surgical trainees' acute stress in real operations or simulation: a systemic review. Surgeon 2017;15:355–65.
[24] Khandelwal S, Bernard AW, Wald DA, et al. Developing and assessing initiatives designed to improve clinical teaching performance. Acad Emerg Med 2012;19:1350–3.
[25] Brunckhorst O, Khan MS, Dasgupta P, Ahmed K. Effective non-technical skills are imperative to robot-assisted surgery. BJU Int 2015;116:842–4.
[26] Dort J, Trickey A, Paige J, Schwarz E, Dunkin B. Hands-on 2.0: improving transfer of training via the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) Acquisition of Data for Outcomes and Procedure Transfer (ADOPT) program. Surg Endosc 2017;31:3326–32.
[27] Guru KA, Esfahani ET, Raza SJ, et al. Cognitive skills assessment during robot-assisted surgery: separating the wheat from the chaff. BJU Int 2015;115:166–74.
[28] Ericsson KA. Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. Acad Med 2004;79(10 Suppl):S70–81, [Review].
[29] Gallagher AG. Metric-based simulation training to proficiency in medical education: what it is and how to do it. Ulster Med J 2012;81:107–13, [Review].
[30] Sullivan S, Ruis A, Pugh C. Procedural simulations and reflective practice: meeting the need. J Laparoendosc Adv Surg Tech A 2017;27:455–8.
[31] Sweet RM. The CREST simulation development process: training the next generation. J Endourol 2017;31(S1):S69–75.
[32] Mackenzie H, Cuming T, Miskovic D, et al. Design, delivery, and validation of a trainer curriculum for the national laparoscopic colorectal training program in England. Ann Surg 2015;261:149–56.
[33] Gardner AK, Timberlake MD, Dunkin BJ. Faculty development for the operating room: an examination of the effectiveness of an intraoperative teaching course for surgeons. Ann Surg 2019;269:184–90.
[34] Hashimoto DA, Sirimanna P, Gomez ED, et al. Deliberate practice enhances quality of laparoscopic surgical performance in a randomized controlled trial: from arrested development to expert performance. Surg Endosc 2015;29:3154–62.
[35] Dulan G, Rege RV, Hogg DC, et al. Developing a comprehensive, proficiency-based training program for robotic surgery. Surgery 2012;152:477–88.
[36] Coleman M, Cecil T, editors. Laparoscopic colorectal surgery: the Lapco manual. CRC Press; 2017,, [chapter 5].
[37] Aghazadeh MA, Jayaratna IS, Hung AJ, et al. External validation of Global Evaluative Assessment of Robotic Skills (GEARS). Surg Endosc 2015;29:3261–6.
[38] Lovegrove C, Novara G, Mottrie A, et al. Structured and modular training pathway for robot-assisted radical prostatectomy (RARP): validation of the RARP assessment score and learning curve assessment. Eur Urol 2016;69:526–35.
[39] Frederick PJ, Szender JB, Hussein AA, et al. Surgical competency for robot-assisted hysterectomy: development and validation of a robotic hysterectomy assessment score (RHAS). J Minim Invasive Gynecol 2017;24:55–61.
[40] Raza SJ, Field E, Jay C, et al. Surgical competency for urethrovesical anastomosis during robot-assisted radical prostatectomy: development and validation of the robotic anastomosis competency evaluation. Urology 2015;85:27–32.
[41] Yang K, Perez M, Hubert N, Hossu G, Perrenot C, Hubert J. Effectiveness of an integrated video recording and replaying system in robotic surgical training. Ann Surg 2017;265:521–6.
[42] Ahlberg G, Enochsson L, Gallagher AG, et al. Proficiency-based virtual reality training significantly reduces the error rate for residents during their first 10 laparoscopic cholecystectomies. Am J Surg 2007;193:797–804.
[43] Abdul-Muhsin H, Patel V. History of robotic surgery. In: Kim CH, editor. Robotics in general surgery. New York, NY: Springer; 2014. p. 3–8.
[44] Kotsis SV, Chung KC. Application of see one, do one, teach one concept in surgical training. Plast Reconstr Surg 2013;131:1194–201.
[45] Pernar LIM, Robertson FC, Tavakkoli A, Sheu EG, Brooks DC, Smink DS. An appraisal of the learning curve in robotic general surgery. Surg Endosc 2017;31:4583–96.
[46] Lee JY, Mucksavage P, Sundaram CP, McDougall EM. Best practices for robotic surgery training and credentialing. J Urol 2011;185:1191–7.
[47] Gallagher AG, Ritter EM, Champion H, et al. Virtual reality simulation for the operating room: proficiency-based training as a paradigm shift in surgical skills training. Ann Surg 2005;241:364–72.
[48] Halsted WS. The training of the surgeon. Bull Johns Hop Hosp 1904; xv:267–75.
[49] Osborne MP. William Stewart Halsted: his life and contributions to surgery. Lancet Oncol 2007;8(3):256–65.