Fundamentals of robotic surgery: A course of basic robotic surgery skills based upon a 14-society consensus template of outcomes measures and curriculum development

Article *in* International Journal of Medical Robotics and Computer Assisted Surgery · September 2014

DOI: 10.1002/rcs.1559 · Source: PubMed

3 authors, including:

Roger Smith
AdventHealth (Florida Hospital)

Richard Satava
University of Washington Seattle

The International Journal of **Medical Robotics** and **Computer Assisted Surgery**

THE INTERNATIONAL JOURNAL OF MEDICAL ROBOTICS AND COMPUTER ASSISTED SURGERY
Int J Med Robotics Comput Assist Surg 2014; **10**: 379–384.
Published online 26 November 2013 in Wiley Online Library (wileyonlinelibrary.com) **DOI:** 10.1002/rcs.1559

ORIGINAL ARTICLE

Fundamentals of robotic surgery: a course of basic robotic surgery skills based upon a 14-society consensus template of outcomes measures and curriculum development

Roger Smith[1]*
Vipul Patel[2]
Richard Satava[3]

[1]*Florida Hospital Nicholson Center, Celebration, FL, USA*

[2]*Global Robotics Institute, Celebration Health, Celebration, FL, USA*

[3]*University of Washington College of Medicine, Seattle, WA, USA*

*Correspondence to: R. Smith, Florida Hospital Nicholson Center, 404 Celebration Place, Celebration, FL 34747, USA.
E-mail: Roger.smith@flhosp.org

Accepted: 23 October 2013

Abstract

Background There is a need for a standardized curriculum for training and assessment of robotic surgeons to proficiency, followed by high-stakes testing (HST) for certification.

Methods To standardize the curriculum and certification of robotic surgeons, a series of consensus conferences attended by 14 leading international surgical societies have been used to compile the outcomes measures and curriculum that should form the basis for a Fundamentals of Robotic Surgery (FRS) programme.

Results A set of 25 outcomes measures and a curriculum for teaching the skills needed to safely use current generation surgical robotic systems has been developed and accepted by a committee of experienced robotic surgeons across 14 specialties.

Conclusions A standardized process for certifying the skills of a robotic surgeon has begun to emerge. The work described here documents both the processes used for developing educational material and the educational content of a robotic curriculum. Copyright © 2013 John Wiley & Sons, Ltd.

Keywords robotic surgery; outcomes measures; educational curriculum

Introduction

In 2004, the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) launched the validated Fundamentals of Laparoscopic Surgery (FLS) curriculum and, together with the American College of Surgeons (ACS), promoted the FLS as a minimum standard before a surgeon should be allowed to perform laparoscopic procedures independently (1). In 2009, the American Board of Surgery (ABS) mandated that, in addition to Advanced Cardiac Life Support (ACLS) and Advanced Trauma Life Support (ATLS), a certificate documenting the successful passing of the FLS exam be included in the application in order to be eligible to sit the examination for certification in General Surgery (2).

During the last decade, robotic surgery has grown through a similar evolution to laparoscopic surgery and is being recognized as an important surgical approach by multiple surgical specialties. Furthermore, it shows every sign of continuing the adoption of more diverse surgical procedures, as manifested by the fact that in calendar year 2012, approximately 450,000 robotic surgical procedures were performed. The number of procedures being performed by robotic surgery has been constantly rising in urology, gynaecology, colorectal, paediatric and numerous other specialties. Expert robotic surgeons and numerous surgical societies and certifying organizations have advocated the need for a unified approach and standardized curriculum for basic training, assessment, testing and certification in robotic surgery skills (3). There have been previous efforts to develop a core curriculum for certifying robotic surgeons (4,5); however, these have been fragmented, with different approaches and outcomes measures emerging from each. This has resulted in conflicting, competing and redundant curricula for the training and the assessment tools for robotic surgery. In addition, these curricula have generally lacked the human and financial resources necessary to complete the most comprehensive, multi-institutional validation that is necessary to gain acceptance at a national level.

Through the combined support of two grants, one to the Minimally Invasive Robotics Association and the other to the Florida Hospital Nicholson Center, a process has been created by a multi-specialty group of participants which unifies the previous attempts to develop a robotic curriculum, which included the current developers of the existing curricula and which expand into a much larger foundation of surgical societies with a stake in this new technology. These grants provide the necessary funding to carry the effort through multi-institutional validation with the support of participants who represent all surgical specialties that are currently performing robotic surgery.

The scope of the curriculum development was limited to the creation of a curriculum (course) that encompassed the cognitive, psychomotor and team training skills required to safely operate a surgical robotic system and perform the most basic of manual and communication skills that would be needed to safely perform any robotic surgery procedure. This curriculum does not include the needs assessment, gap analysis, pre-operative care or post-operative care – it is a skills-based curriculum focused upon the skills needed in the operating room. It is assumed that all the above pre- and post-operative education and training has been completed before bringing the patient into the operating room.

Materials and methods

Participation in this effort was invited from multiple certifying boards, professional surgical societies and associations that represent international practitioners and regulators of various surgical specialties, as well as the US Department of Defense (DoD) and Veterans Health Administration (VHA). The conference participants were official representative members of these organizations or agencies and were selected by their organizations to provide insight into the needs of the organization. A complete list of the participating organizations is given in Table 1 and a list of the individual participants is given in the Acknowledgements section of this paper. While they do not formally represent an endorsement or acceptance of the results at this interim period of the curriculum development, and their participation does not imply acceptance by the societies, boards or agencies, at the completion of the validation trials, the organizations will review the final results for endorsement or as a requirement for surgical training. This project is an effort to provide the stakeholders with the best scientific evidence upon which to base their decisions regarding implementation of a fundamental curriculum to meet their needs, while reducing redundancy, competition and duplication of effort.

Each consensus conference was conducted over a 2 day period, using a task analysis followed by a modified Delphi method (6) to achieve consensus on the materials that were created and accepted by the group. The concepts and criteria contributed by the members were analysed for commonality to create a list of critical items in robotic surgery. Previously published material from a single institution's curriculum was used as a template for initial idea generation (7,8). The individual outcomes measures and curriculum materials were itemized and votes taken on their importance according to each participant. This method led to a composite ranking of outcomes measures which was captured in a draft report. This report was then circulated to each participant for his/her private, anonymous deliberation (classic Delphi method). Following the editing of the comments on the initial draft, a second classic Delphi round was sent to each participant, who then submitted a second set of scores, which were informed by the first composite scores but anonymous to other group members. This classic Delphi method led to a higher level of consensus around the measures and the curriculum. It also identified those items for which there was little group support. Items with

Table 1. Organizational representation in fundamentals of robotic surgery

Accreditation Council of Graduate Medical Education (ACGME)
American Association Gynecologic Laparoscopy (AAGL)*
American College of Surgeons (ACS)
American Congress of Obstetrics and-Gynecology (ACOG)
American Academy of Orthopedic Surgeons (AAOA)
American Association of Colo-rectal Surgeons (ASCRS)
American Association of Thoracic Surgeons (AATS)
American Board of Surgery (ABS)
American Urologic Association (AUA)*
Association of Surgical Educators (ASE)
European Urology Association (EUA)
Minimally Invasive Robotic Association (MIRA)†
Society of American Gastrointestinal and Endoscopic Surgeons (SAGES)*
Society for Robotic Surgery (SRS)
Residency Review Committee (RRC) – Surgery
Royal College of Surgeons-Australia (RCSA)
Royal College of Surgeons-Ireland (RCSI)
Royal College of Surgeons-London (RCSL)
US Department of Defense (DoD)†
US Department of Veterans Health Affairs (VHA)

*Official representative participation.
†Funding organizations.

DOI: 10.1002/rcs

little group support were removed from the list of outcomes measures and from the outline of the curriculum.

The first conference on outcomes measures was attended by 20 participants, including surgeons, scientists, educators, representatives of governing and certification organizations and facilitators. The ranking of the tasks identified was done by a subset of nine experienced clinical surgeons. Participants who were not surgeons abstained from the scoring process.

The second conference on curriculum development was attended by 38 surgeons, scientists, medical educators, behavioural psychologists, psychometricians and facilitators. This group reviewed and became familiar with the material from the first conference. Thereupon, they were divided into three working groups to develop the detailed information in the curriculum that focused on didactic and knowledge-based information, psychomotor skills and team training and communications. At the conclusion of the three focused workshops, all participants reviewed the report of the separate workgroups, consolidated the three sections back into a single curriculum, which was then deliberated until consensus was reached and then voted upon. Similarly, the final ranking of the material developed was limited to experienced surgeons within the group. The role of the scientists, educators, psychologists and psychometricians was to ensure that the material created by the surgeons was structured into effective and valid educational and testing products.

The products from these meetings will go through a multi-site validation trial in which subjects are trained using these materials and the results collected, evaluated and used to modify the materials as necessary.

Results

The first consensus conference (outcomes measures) resulted in a list of 25 outcomes measures, which the group agreed should be the minimal skills needed by a surgeon seeking to safely perform robotic surgery, regardless of his/her specialty. These included eight pre-operative, 15 intra-operative and two post-operative skills, which are shown in Table 2. The resulting documents also provided detailed definitions, descriptions, errors, outcomes and metrics for each of these skills [Martino M. Basic skills curriculum for robotic gynecologic surgery (unpublished)].

The second and third consensus conferences (curriculum development), which focused on actually creating the curriculum and its content, initially resulted in outlines and principles for the creation of a curriculum to teach the previously identified list of skills and knowledge (Table 3) (9). This document was then expanded into a fully detailed curriculum by clinical surgeons working in conjunction with experienced surgical educators, behavioural psychologists, statisticians and psychometicians. The result was a full life-cycle curriculum that consists of three components: cognitive skills, psychomotor skills, and team training and communication skills.

Table 2. FRS outcomes measures

Pre-operative	Intra-operative	Post-operative
System settings	Energy sources	Transition to bedside assistant
Ergonomic positioning	Camera control	Undocking
Docking	Clutching	
Robotic trocars	Instrument exchange	
Operating room set-up	Foreign body management	
Situation awareness	Multi-arm control	
Closed-loop communicationss	Eye–hand instrument coordination	
Response to system errors	Wrist articulation	
	Atraumatic tissue handling	
	Dissection – fine and blunt cutting	
	Needle driving	
	Suture handling	
	Knot tying	
	Safety of operative field	

Table 3. FRS curriculum principles

Cognitive	Psychomotor skills	Team training
Lecture and video	Physical test device	Interdisciplinary team
Introduction to robotic systems	Single integrated device	WHO pre-operative checklist
Pre-operative activity	3D working space	Robotic-specific communication
Intra-operative activity	Based on existing validated tasks	Post-operative debriefing
Post-operative activity	Affordable design	Team crisis response
Each activity includes goals, conditions, standards, metrics, errors	High fidelity for examination, lower fidelity for training	
	Ease and reliability of scoring	

Cognitive skills

The didactic and cognitive (knowledge base) working group created an outline of the material which should be taught in lecture format. Since the training was in basic skills (not surgical procedures), there were no ’steps of the procedure’ which are traditionally included when developing a procedure-focused curriculum. This curriculum included:

1. Introduction to the principles and functionality of robotic surgical devices.
2. Pre-operative set-up of equipment and positioning of patient and staff, placement of ports, check lists and all activities required of the surgeon before sitting at the robotic console.
3. Intra-operative use of a robot, description of the critical psychomotor skills, surgeon ergonomics, visual field control, operative control of the robot, necessary instruments and supplies. Also included were surgeon communication skills from the console to the operating room team (team training).
4. Post-operative steps for shutting down the robot, removing a robot from the operative field and transitioning the patient to a gurney.

Each of these included an explicit list of passing criteria and errors that can occur in the process.

Psychomotor skills

The psychomotor skills working group initiated their work by defining the seven principles that should be applied in selecting or designing a psychomotor skills device for robotic surgery. Those principles were:

1. The tasks should be three-dimensional in nature.
2. The tasks designed for testing should be such that they have multiple learning objectives that incorporate multiple skills from the outcomes measures.
3. The skills should be designed to train the full capability of the robotic system, to include skills and tasks that are not possible in open or laparoscopic surgery.
4. Implementation of the tasks and the resultant method for teaching should not be cost-prohibitive.
5. High-fidelity models should be used for testing. Training can use lower-fidelity devices and methods.
6. Tasks should be easy to administer to ensure inter-rater reliability (IRR).
7. The tasks should be designed for implementation with physical objects and devices. The device will be developed initially in virtual reality (VR) as a CAD/CAM model, from which the actual physical models will be ‘printed’ with stereolithography (the VR model objects will be identical to the physical objects), creating a training experience that would be identical in both the virtual and real world.

The group then identified 16 of the 25 skills that contained psychomotor features. In order to implement this psychomotor skills curriculum, 10 tasks were created for the dome-shaped device, which could be used to train and measure the 16 skills. Three tasks were drawn from FLS (with slight modifications); others were selected from existing educational programmes presented by participants and found in the published literature (4,7,8), and designs for new task devices were proposed and debated by the participating surgeons:

1. FLS peg transfer.
2. FLS suturing and knot tying.
3. FLS pattern cutting.
4. Running suture.
5. Dome with four towers for ambidexterity.
6. Vessel dissection and clipping.
7. Fourth arm retraction and cutting.
8. Energy and mechanical cutting.
9. Docking task (new design).
10. Trocar insertion task (new design).

For each of these, the group also identified the associated task description, conditions, metrics and errors. These details can be found in the milestone report of the event (10).

The group felt that, for ease and simplicity of implementing the training of the tasks and skills, it was important for all of these tasks to be performed on a single integrated device, which could be scored by visual observation for training, assessment and testing. Incorporated into the planning was that the design of the device would permit future adaptation of more sophisticated automated scoring by an identical device which was either a mechanical or computer-based (VR) version. Toward this end, they created the initial design for the ’FRS dome’ shown in Figure 1. Prototypes of this dome have been created to test the usability and reliability of the device itself during a pilot study, and the training and assessment effectiveness of the device will be evaluated during the multi-institutional validation trials of the FRS curriculum.

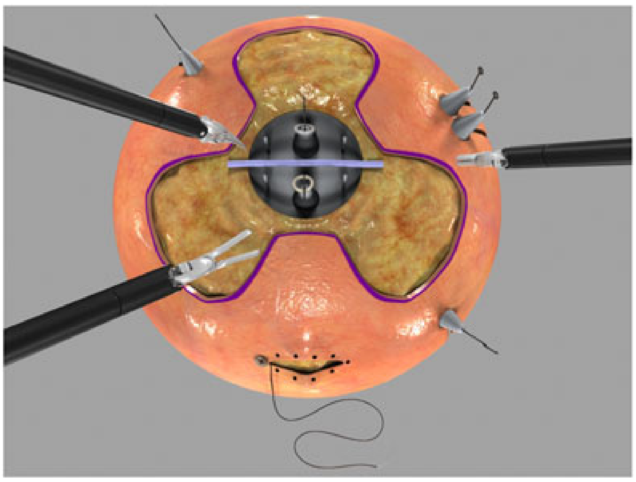

Figure 1. FRS dome device design

DOI: 10.1002/rcs

Team training and communications

The team training and communications working group prefaced their work by defining the importance of team training in a robotic environment. They identified the following principles as essential to successful team-based operations and training:

1. Inclusion.
2. Empowerment.
3. Person-specific.
4. Reiterative.
5. 'Just in time'.
6. Ownership.
7. Risk management/quality improvement – closed loop communication.

They stated that existing programmes, such as TeamSTEPPS®, can be applied to robotic teams. Their curriculum follows a checklist format and is conceptually derived from the standard WHO checklist. For robotic training they recommended the following checklists:

1. *Pre-operative*. Addressing general situation, surgeon, anaesthetist, nurse/OPD, and surgical site infection and robotic docking, in addition to addressing anaesthesia, patient, bedside assist, procedure-specific checks and trouble shooting.
2. *Intra-operative*. Addressing the communication that occurs within a team throughout the operation. Special emphasis was placed upon developing communication skills for the surgeon and the team once surgery has begun, because the surgeon has no visual contact with the remainder of the operating team during the procedure.
3. *Post-operative*. Undocking, patient transport and final debriefing.

Based on these, the groups generated outlines for a full curriculum to teach these information and communication skills. Those were then expanded into a full curriculum by an experienced surgical educator, which is currently being developed into a publicly accessible online education system.

Discussion

A consensus conference process, involving members from major stakeholder organizations in surgical training, governance and certification across multiple specialties, was implemented, with the result of a curriculum for the most important outcome measures for the safe conduct of robotic surgery. The development of FRS is multi-specialty, system agnostic and follows decades of experience in other industries at developing such education, training and assessment platforms.

This curriculum for training and assessment should be executed not by a time-based course limited by number of days, sessions, etc., but rather in a competency-based fashion, that is, continuing to train until the student's learning curve has reached the benchmark values (set by the mean of the learning curve of experienced surgeons). With such training and assessment, a learner should be able to demonstrate proficiency in basic robotic surgery skills and should be capable of passing the requirements of high-stakes testing and evaluation that would lead to his/her certification in technical skills. The current training programme, which has been designed by and is taught by the device manufacturer, presents excellent information and hands-on experience with the equipment. However, it is a time-based exposure and attendance programme, with no measurement of the proficiency of the attendees.

The curriculum, conference reports and associated artifacts from the process will be transitioned to an independent, objective, unbiased professional organization with the mission and capability to develop and administer testing in a manner that meets requirements for certification. The goal of this specific manuscript is to provide a detailed process and methodology for developing a curriculum that is template-based, which is easy to use, flexible to meet the needs of many different specialties, reduces redundancy and competition and, because of its modularity, is cost efficient and reduces the time to develop subsequent curricula.

Acknowledgements

This project is a collaboration of leading robotic surgeons and educators. The following have all participated in, and contributed to, the creation of the materials reported here: A. Advincula; R. Aggarwal; A. Al Ansari; D. Albala; R. Angelo; M. Anvari; J. Armstrong; G. Ballantyne; M. Billia; J. Borin; D. Bouchier-Hayes; T. Brand; J. Cannon-Bowers; S. Chauhan; R. Coelho; S. Cuschieri; B. Dunkin; S. Dunlow; V. Ficarra; A. Gallagher; L. Glazerman; A. Goh; T. Grantcharov; D. Hananel; J. Hebert; R. Holloway; J. Hubert; W. Judd; P. Kenneth; K. Kim; M. Koch; T. Kowalewski; R. Kumar; K. Kunkler; G. Lee; T. Lendvay; R. Leveillee; J. Levy; G. Lewis; G. Maddern; S. Magnuson; P. Manuela; M. Marohn; D. Maron; M. Martino; P. Neary; E. Parra-Davila; V. Patel; C. Perrenot; S. Ramamoorthy; K. Rha; J. Riess; B. Rocco; R. Rush; R. Satava; B. Sayers; D. Scott; N. Seymour; N. Siddiqui; M. Sinanan; R. Smith; D. Stefanidis; C. Sundaram; R. Sweet; E. Verrier; G. Weinstein; V. Wilcox. This study was collaboratively supported by grants to the Minimally Invasive Robotics Association and to the Florida Hospital Nicholson Center, and partially sponsored by the US Department of the Army (Award No. W81XWH-11-2-0158) to the recipient Adventist Health System/Sunbelt Inc. (Florida Hospital Nicholson Center); the US Army Medical Research Acquisition Activity (820 Chandler Street, Fort Detrick, MD 21702–5014, USA) is the awarding and administering acquisition office. The

content of the information does not necessarily reflect the position or the policy of the US Government, and no official endorsement should be inferred.

References

1. Peters JH, Fried GM, Swanstrom LL, *et al*. SAGES FLS Committee. Development and validation of a comprehensive program of education and assessment of the basic fundamentals of laparoscopic surgery. *Surgery* 2004; **135**(1): 21–27.
2. ABS news release. ABS to require ACLS, ATLS and FLS for general surgery certification; 15 August 2008: http://www.absurgery.org/default.jsp?news_newreqs [accessed 6 November 2012].
3. Zorn KC, Gautam G, Shalhav AL, *et al*. Training, credentialing, proctoring and medicolegal risks of robotic urological surgery: recommendations of the Society of Urologic Robotic Surgeons. *J Urol* 2009; **182**(3): 1126–1132.
4. Goh AC, Goldfarb DW, Sander JC, *et al*. Global evaluative assessment of robotic skills: validation of a clinical assessment tool to measure robotic surgical skills. *J Urol* 2012; **187**(1): 247–252.
5. Hung AJ, Patil MB, Zehnder P, *et al*. Concurrent and predictive validation of a novel robotic surgery simulator: a prospective, randomized study. *J Urol* 2012; **187**(2): 630–637.
6. Dalkey N. The Delphi method: an experimental study of group opinion. RAND Corp. Memorandum (RM-5888-PR), 1969.
7. Dulan G, Rege RV, Hogg DC, *et al*. Proficiency-based training for robotic surgery: construct validity, workload, and expert levels for nine inanimate exercises. *Surg Endosc* 2012; **26**(6): 1516–1521.
8. Dulan G, Rege RV, Hogg DC, *et al*. Content and face validity of a comprehensive robotic skills training program for general surgery, urology, and gynecology. *Am J Surg* 2012; **203**(4): 535–539.
9. Satava RM, Smith RS, Patel VR, et al. Fundamentals of Robotic Surgery Consensus Conference I: Outcomes Measures, report from consensus conference.
10. Satava RM, Smith RS, Patel VR, *et al*. Fundamentals of Robotic Surgery Consensus Conference II: Curriculum Development, report from consensus conference.

DOI: 10.1002/rcs