Development of physical robotic surgery training exercises based on a systematic literature review

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Abstract

Purpose

Robotic surgery is a promising surgical technique. As robotic platforms expand there is an increasing need for validated training exercises for surgeons to explore, develop, maintain and research the skills required for proficient use. The aim of this study was to evaluate the literature to inform development of an evidence-based physical simulator training platform for use with a retired da Vinci Surgical System (IS1200; Intuitive Surgical Inc., Sunnyvale, Ca).

Methodology

A literature review was performed on Scopus (English, all years) focused on physical training tasks for robotic surgery skill development. Retrieved data was applied to guide the development of an optimal suite of tasks based on pre-defined criteria. Identified exercises were manufactured in-house at the Auckland Bioengineering Institute for use with the da Vinci Surgical System IS1200. Medical Students volunteers tested feasibility and face validity of the complete training suite.

Results

Based on the literature review, evidence-based robotic surgery skills identified as priorities for physical simulators were: camera control, clutching, EndoWrist® dexterity, atraumatic handling, coordinated two handed control, cutting, needle driving, suture handling and knot tying. The following validated training tasks were identified as optimally covering these core skills: Peg Transfer, Ring Rollercoaster, Rubber Band Transfer, Pattern Cut, Suture Sponge and Running Suture. Each simulation was able to be completed satisfactorily by medical students. Areas of potential improvements were identified in this pilot run to make the training suite more feasible and efficient.

Conclusion

An optimal and validated suite of physical simulations were successfully identified and manufactured for use with a da Vinci Surgical System. While each task is based on validated literature, further study is now needed to define the construct validity of the training suite overall using experts.

Introduction

Over the past decade, robotic surgery has developed into a promising surgical technique. The most commonly used system is the da Vinci Surgical System (Intuitive Surgical Inc., Sunnyvale, CA). It consists of two main components; the surgeon's console and the patient side cart (Figure 1). The patient side cart contains robotic arms which hold instruments and the camera, that are inserted into the patient via ports akin to laparoscopic surgery. The surgeon's console contains two master controllers, which translate movements of the surgeon's hands to the robotic arms. All over the world, various specialties notably urology, gynaecology, head and neck and general surgery have begun utilising surgical robots in procedures.[1]

There are numerous recognised advantages of robotic surgery that have resulted in its increasing worldwide utilisation; it is minimally invasive, which theoretically contributes to a shorter recovery time, less post-operative pain, lower blood loss and improved cosmesis;[2] it is ergonomically beneficial to surgeons; it can be more precise due to the translation of the minute hand movements to the instrument tips without tremor; and there is better visualisation and access to difficult to reach areas.[3]

The adoption of robotic surgery in New Zealand has been less widespread than other countries. Due to the steep learning curve and high costs of care and training it has been difficult for robotic surgery to gain a foothold in the surgical fields of New Zealand. Currently, there are only three privately-owned hospitals available to carry out robotic surgery in New Zealand and only a handful of surgeons adequately trained to carry out these procedures.

The University of Auckland has received a significant donation of a decommissioned da Vinci Surgical System (IS1200) from a local private hospital. The robot is housed at the Auckland Bioengineering Institute and now offers an outstanding and only opportunity to contribute to exposure, training and research in robotic surgery.

The aim of this project was to develop a physical simulation setup to enable practice and research on the da Vinci Surgical System. First an analysis of literature on various physical robotic surgical training tasks was carried out, focusing on information useful in guiding development of tasks. This was then used to create an optimal suite of training tools based on technical requirements, validation, simplicity and cost-effectiveness. Lastly, the devised training simulators were tested using a group of non-surgeon volunteers.

Figure 1 Surgeon's console, controlling instruments on patient side cart, which is docked into the patient (mannequin torso) through ports.

Literature Review: Methods

A broad search of English language literature, from all years, was performed using Scopus, with the keywords "robotic AND surgery" and "physical OR inanimate" and "training". References of published review articles were manually searched to supplement the search results. Articles detailing the development, validation and use of physical training simulations in robotic surgery by both experts and novices over any time period were included. Review articles and studies describing use of virtual reality systems or technologies apart from the da Vinci Surgical System were excluded from analysis.

One author (N.S) initially screened titles and abstracts to identify potentially relevant articles. Full texts were then obtained and further screened for inclusion based on information relevant to development and validation of physical training simulations for training in robotic surgery. The information extracted from each study included the program name, technical skills identified, physical tasks developed, and validation methods and results (Table 1).

Due to the nature of the information identified, a quantitative synthesis was not possible, therefore the findings were discussed in a narrative format.

Literature Review: Results

The search yielded 130 results, of which 115 were excluded from analysis after the abstract review as most described virtual reality simulations or did not detail the original development of physical simulations. One additional study was identified from existing review references. Of the remaining 16 studies, a further ten were excluded after reviewing the full text. Thus, six studies were successfully included in the literature review.[7-12] The following is a narrative summary of concepts identified relevant to the development of our own training suite of physical training simulations

Core Technical Skills

Due to its unique approach, the skills required for proficient robotic surgery are practically different, but fundamentally and theoretically similar to other modes of surgery, especially laparoscopic surgery. For example, all modes of surgery require adequate hand-eye coordination, wrist articulation, depth perception, coordinated two-handed movement, and the basic tenets of retraction, dissection, cutting, needle driving, suture handling and knot tying.[10,11] After reviewing the literature, we identified a set of basic core skills that are unique to robotic surgery and are fundamental to mastery of the above skills on the robotic platform: effective camera control, EndoWrist® instrument dexterity, clutching and atraumatic handling.

A feature unique to robotic surgery is that the camera as well as the instruments are controlled by the one surgeon.[1] Effective camera control involves manoeuvring the camera smoothly to obtain a suitable view, without collisions and without losing sight of the instruments.[10]

In robotic surgery, the hand and wrist position of the surgeon is translated exactly to the movement of the specific EndoWrist® instruments (Figure 2).[1] This is directly compared to laparoscopic surgery where movements are inversed. Effective EndoWrist® dexterity is therefore important to train.

The field of view changes often during the surgery, and because both the camera and instruments are moved with the master controllers, it is difficult to maintain the correct hand and wrist position when operating. The clutch allows the surgeon to reset his hands back to a resting position whilst keeping the instruments still to maintain a comfortable range of motion.

A major drawback of robotic surgery is the lack of haptic feedback, so the ability to gauge force when handling tissues and objects is essential to proficient use.[3,4]

Program Name (authors)	Technical skills identified	Physical tasks developed	Validation methods and results.
FIRST (Goh et al.)[7]	Expert robotic surgeons used to identify essential technical skills, but details not available	Penrose tube, Clover pattern cut, 3D dome peg transfer, Circular needle target	Participants to warm up and watch an instructional video Exit questionnaire provided face and content validity Scoring based on Dulan et al.[11] Performance significantly different for all tasks between novice and expert, proving construct validity
BSTC (Foell et al.)[8]	EndoWrist® and camera manipulation, instrument clutching, object manipulation, needle driving, suturing, knot tying	Ring transfer between pegs and passing a needle through a series of small rings	Time to completion and number of errors for each task shown to be significantly improved pre- and post-course
R-OSATS (Siddiqui et al.)[9]	Depth perception/accuracy, force/tissue handling, dexterity, efficiency	Rubber band transfer, rollercoaster, suture sponge, running suture, figure of eight knot	Each skill assessed from 1-5. Demonstration video of each task shown 1 minute of practice and 6 minutes to complete each exercise Persons with more robotic experience scored significantly higher than those with less.
FRS (Smith et al.)[10]	Camera control, clutching, foreign body management, multi-arm control, hand-eye instrument coordination, wrist articulation, atraumatic tissue handling, dissection, cutting, needle driving, suture handling, knot tying, safety of intraoperative field	Ring tower transfer, knot tying, railroad track running suture, 4th arm cutting, cloverleaf pattern cut, vessel energy dissection	Use of a single, multi-function device Validation study yet to be published
Proficiency based robotic curriculum (Dulan et al.)[11]	Energy source control, camera, clutching, 4th arm control, basic hand-eye coordination, wrist articulation, depth perception, instrument to instrument transfer, atraumatic handling, blunt and fine dissection, retraction, cutting, interrupted and running suture	Peg transfer, Camera movement to view rectangles, rubber band transfer, simple suture, 4th arm cutting, pattern cut, running suture	Participants shown a video and allowed to practice each task once Score = cut off time – completion time – (weighting factor x sum of errors) Manual controls placed back into a neutral position Baseline novice and expert performances were significantly different
Nine inanimate exercises (Jarc et al.)[12]	–	Ring rollercoasters (4), suture sponges (3), interrupted suture, figure of eight suture	Standardised docking model created Verbal overview of each task given Scoring based on Dulan et al.[11] Experienced surgeons performed significantly better than new surgeons

Table 1 Literature review summary

Figure 2 EndoWrist® instruments which translate and scale hand/wrist movements into movements of the instrument tips.

Physical tasks for assessment of skills and their development

As described previously, most core skills of surgery are common between the different technical modalities, therefore many papers[8-11] adapted tasks already well validated as part of the Fundamentals of Laparoscopic Surgery program (FLS) developed by the Society of American Gastrointestinal Endoscopic Surgeons.[6] Smith et al.[10] describe the principles of designing tasks well; they must be 3D in nature; test multiple skills; train the full capability of the robot; not be cost-prohibitive; easy to administer; and implement physical objects.

Tasks or specific elements of tasks from the literature review were assessed to inspire use in our study. These included: Peg transfer,[10,11] transferring pegs between hands to encourage usage of both hands,[11] ring rollercoaster in different planes to encourage proper wrist articulation,[12] use of rubber band transfer to approximate tissue tension and assess atraumatic handling,[9,11] circular pattern cut,[5,7,10,11] use of a sponge to simulate tissue turgor when suturing,[7,9,12] around the world and big dipper exercises to assess driving in various directions and backhand needle driving,[7,9,12] and running suture and knot tying to approximate a wound.[7,9-12] Other tasks described in studies were assessed but not used either due to not meeting enough criteria to warrant testing, not assessing the most relevant skills, assessing skills that are better tested in other tasks, taking too much time to carry out, or lack of resources.

Validation and Testing

Siddiqui et al.[9] described scoring the performance on tasks subjectively based on depth perception/accuracy, force/tissue handling, dexterity and efficiency, with each category given a score from 1-5. Dulan et al.[11] described a more objective scoring method where a score was given according to the formula: score = cut off time – completion time – (weighting factor x sum of errors). The weighting factor depends on how severe the errors are (10 for most). The cut off time was based on the average time that an expert robotic surgeon takes for each task.[11] Jarc et al.[12] alternatively described setting the cut off time as the mean novice time + 3 standard deviations (SD). This scoring option objectively quantifies performance by balancing both efficiency and accuracy.[12]

Errors in robotic surgery depend on the task, but some errors such as instrument collisions, crossing over instruments and excessive force are applicable to all tasks.[7,10-12] The use of video technology used to both introduce the participant to the tasks and their objectives and also record each participant's attempt for later blinded assessment seemed an effective way to assess participants.[7,8,10,11] A challenge for physical simulation exercises compared to virtual reality is to keep the starting conditions the same for each participant, so that the only difference in performance is based on skill. The use of a custom docking model, prepared and setup by the same person, enables consistency and repeatable completion of tasks, allowing better comparisons.[10,12]

Physical Simulation Designs and Testing

Materials and Methods

Based on the review, evidence-based intra-operative robotic surgery core skills for development included: camera control, clutching, EndoWrist® dexterity, atraumatic handling, coordinated two handed control, cutting, needle driving, suture handling and knot tying. These skills best covered the range of robotic-specific and overall surgery specific-skills required for competency in robotic surgery operations based on expert analyses from the results of the literature review.

The following tasks were created based on the literature review to optimally train and assess the core skills: Peg Transfer, Ring Rollercoaster, Rubber Band Transfer, Pattern Cut, Suture Sponge, and Running Suture (Figure 4, Table 3). Tasks were selected based on the principles described by Smith et al., simplicity of design, meeting our own technical requirements, and the level of their validation.

To provide the best simulation of a real surgery, and for docking of the robotic arms into ports for proper function, a hollow mannequin torso was adapted to create a simulation patient with space to place the tasks inside. Multiple holes were created on the abdomen, providing flexibility in port position, and covered with neoprene, to best simulate the turgor of skin (Figure 3). Velcro was used for stability quick task changes. All work was carried out at the workshop at Auckland Bioengineering Institute using simple raw materials such as wood, wire, pins, rubber bands, latex gloves, sponge, silicon sheet, and suture needles. The only consumable materials were the latex gloves and sutures. The sponge and silicon sheet experience wear and tear with frequent use.

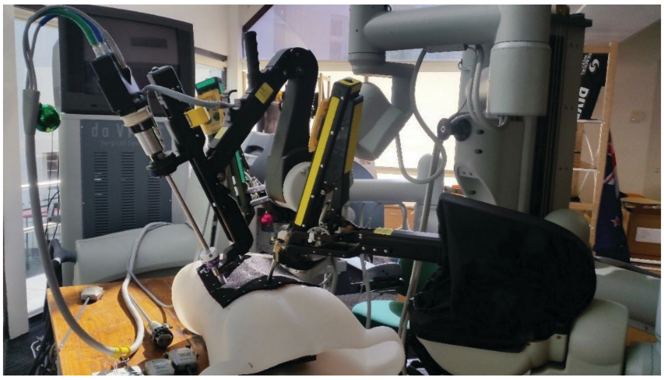


Figure 3 Mannequin torso with neoprene covering

Initial steps in developing training tools entails proving feasibility and validity. Feasibility is the measure of whether an assessment process is capable of being carried out. Validation determines whether the assessment succeeds in testing the competencies that it is designed to test. Validity is made up of face validity (degree to which the tool is testing what it is meant to be testing), content validity (utility as a training tool), construct validity (ability of training too to distinguish between expert and novice) and concurrent validity (correlation with gold-standard). The tasks, individually, have been well validated, as described in the literature review. As a pilot run, this project was able to test feasibility and face validity of the training suite overall.

A video was created outlining the objectives of each task, the errors and an example of how each task was expected to be performed (Figure 2, Table 3). Five fifth and sixth year medical student volunteers were invited to try out the tasks. Each were asked about their experience with surgical simulators and time practicing surgical skills such as suturing before commencing. The robot was introduced verbally. The participant was shown the video and given 5 minutes on each task to practice. Video recording software was started. Docking and instrument exchanges were carried out by the examiner and the master controllers re-centred to a neutral position before each exercise to maintain consistency. The participants were timed for each task, and errors counted. Continuous observations about the feasibility of each task were made by the examiner. Following completion, participants were asked about their thoughts on the feasibility, difficulty and face validity of the tasks.

Results

Participants had minimal to no experience with surgical simulators, and specific time spent practicing suturing was an average of 1-5 hours. Participants were able to complete all the tasks in a reasonable time. The time taken for each task varied considerably (Table 2). Cut off times arbitrarily set from novice practice were too short in some tasks to be of use in scoring the participants. New cut off times can now be created by using the formula (mean novice time + 3 SD) described by Jarc et al.[12] Specific areas of difficulty which commonly led to errors included; controlling the force applied to objects, especially in the peg transfer task and suturing tasks; depth perception; frequent clutching to maintain neutral hand position and instruments within field of view (assessed well in Ring Rollercoaster); adequate suturing and knot tying technique, probably due to minimal suturing experience. From participant feedback and observation, Suture Sponge was more difficult and took a longer time than anticipated. On the other hand, Rubber Band Transfer may have been too simple, and we could look at ways to incorporate handling of rubber bands into the other tasks. The mannequin torso and the running suture tasks were noted to have greatly added to the face validity and all tasks were noted to be testing their relevant core skills effectively.

Task	Time (mean ± SD)	Errors (mean ± SD)
Peg Transfer	447.2 ± 135.5s	5.8 ± 5.6
Ring Rollercoaster	309.4 ± 65.1s	4.0 ± 2.9
Rubber Band Transfer	332.8 ± 61.9s	2.4 ± 2.1
Pattern Cut	326.8 ± 43.7s	7.4 ± 2.6
Suture Sponge	830.0 ± 47.8s	8.6 ± 2.1
Running Suture	630.4 ± 131.9s	5.4 ± 1.8

Table 2 Mean completion times and number of errors made by participants for each task

Discussion

Robotic surgery is appealing, and its future is promising with new devices expected in the coming years from Medtronic, Samsung, Cambridge Medical Robotics and a collaboration between Johnson & Johnson/ Google. With the availability of the surgical robot at the University of Auckland and the new training suite, it is bound to create interest in the surgical field from medical students and existing surgeons, thus creating a platform upon which the robotic surgical field can grow in New Zealand also. Many non-surgical doctors would also benefit from knowing about and experiencing robotic surgery as it becomes a popular option for their patients in the future.

Simulation to assess proficiency is especially important in robotic surgery as the mentoring surgeon cannot take over when patient safety is compromised as in conventional or laparoscopic surgery.[2] Although physical simulation is becoming less popular with the advent of virtual reality, they represent a relatively inexpensive and reproducible means of training, which is platform independent and will remain relevant as robotic systems evolve.[7] Physical simulators are also a more flexible research tool than virtual reality systems, which require complex programming and hardware.[7] However, virtual reality systems can provide better metrics for accurate measurement of proficiency.[4]

This training suite provides a valuable platform for surgical robotics training, teaching and research in New Zealand. Only six tasks were created, as surgeons are known to have very little free time available, and the effort in learning the skills for robotic surgery can be tiring. The learning curve may have been underestimated for first time users of the robot, especially medical students that also have relative inexperience with suturing in general. Our focus was solely on intra-operative skills to guide development of tasks. Non-technical (extra-operative) skills such as learning how the robot works, setting up and troubleshooting the robot may have been helpful in reducing the initial steep learning curve, and can be considered in further studies.

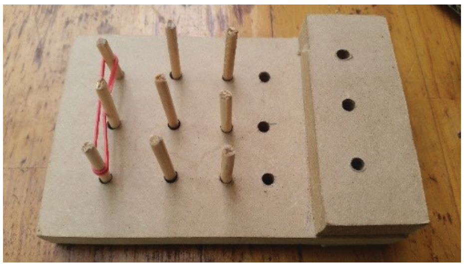
In terms of limitations, adapting tasks from the literature review to low-cost alternatives, whilst still maintaining their purpose in testing the surgical skills effectively was a major challenge. For example, we had to find silicon as an adequate substitute for Penrose tubes in suturing tasks. Our robot also did not have a functional fourth arm and also did not have energy sources connected, which eliminated tasks using the fourth arm and diathermy, which are both important for operations. Virtual reality simulators may thus be a feasible option to overcome technical hurdles. Due to the lack of availability of expert robotic surgeons to validate the tasks and time constraints, this study was not yet able to adequately provide content or construct validity, however feasibility and face validity were obtained by the few medical student volunteers. From the results, tweaking of exercises to make them quicker to complete and easier will likely be beneficial. Having experts carry out the exercises will likely reduce the common errors made by medical students in suturing and atraumatic handling. Experts will also greatly add to understanding of how difficult the tasks are, provide appropriate completion times and provide evidence for content and construct validity.

Conclusion

This study aimed to review the literature on existing physical simulation tasks for robotic surgery, and create a suite of inanimate, cost-effective training tasks for use with a recently decommissioned da Vinci Surgical System (IS1200), donated to the University of Auckland. After reviewing the literature, the relevant core skills and tasks to most effectively test these skills were identified. All tasks were then successfully adapted and created at the Auckland Bioengineering institute. Medical student volunteers tested these tasks. The next step will be to perform a validation study with experts for the physical simulator tasks.

Task 1. Peg transfer	Task 2. Ring rollercoaster	Task 3. Rubber band transfer
Specific skills tested: depth perception, atraumatic grasping, hand-hand transfer, force control **Specific errors:** damaging pegs, dropping pegs out of view **Cut off time:** 600 seconds **Materials needed:** wooden pegs, wooden board with holes big enough for pegs to fall, rubber band **Instruments:** 2 Maryland graspers (or any grasper big enough to hold pegs)	**Specific skills tested:** clutching, vertical and horizontal plane changes, hand-hand transfer, instrument positional awareness, awareness of tension **Specific errors:** lifting track off base, ring drops **Cut off time:** 480 seconds **Materials needed:** pliable metal wire, wooden base, rubber rings. **Instruments:** 2 large needle drivers	**Specific skills tested:** clutching, awareness of force **Specific errors:** tearing rubber band, letting go of rubber band outside of designated area **Cut off time:** 300 seconds **Materials needed:** rubber bands, pegs, wooden base. **Instruments:** 2 large needle drivers
Task 4. Pattern cut	**Task 5. Suture sponge**	**Task 6. Running suture**
Skills tested: tension control, cutting, precision and dexterity, atraumatic handling **Specific errors:** cutting outside the line, cutting second layer **Cut off time:** 480 seconds **Materials needed:** latex gloves, permanent marker, pegs, peg board. **Instruments:** curved scissors (in dominant hand), Maryland grasper	**Specific skills tested:** accurate needle driving including backhand, awareness of force **Errors:** tearing sponge, missing first target, dropping needle out of view **Cut off time:** 900 seconds **Materials needed:** high density foam, rubber bands, base. **Instruments on each arm:** 2 large needle drivers	**Skills tested:** suture handling, needle driving, two-handed coordination in pulling suture through, knot tying **Errors:** missed targets, fraying/breaking suture, improper knot, wound not approximated **Cut off time:** 600 seconds **Materials needed:** silicon sheet, pegs, peg board **Instruments on each arm:** 2 large needle drivers

Table 3 Description of the tasks tested by study participants using the surgical robot

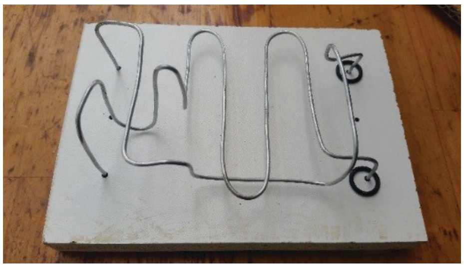


Task 1: Peg transfer

1. Move all 6 pegs to the empty set of holes by lifting with the left hand, transferring, and placing with the right hand

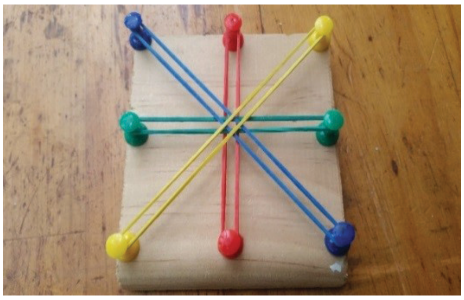
2. Retract the rubber band with the right hand, lift peg with left hand, transfer and place with the right hand, while retracting rubber band with the left hand

3. Opposite of step 1; move all 6 pegs back to their original places by lifting with right hand, transferring and placing with left hand



Task 2: Ring Rollercoaster

Move each ring individually along the track to the other side, without letting go of it



Task 3: Rubber band transfer

1. Take each rubber band off, and place it to the right. Do not let go of the rubber band until it is completely off both pegs

2. Place the rubber bands back as they were, with the double twists on both sides of the red and green pegs

Task 4: Pattern cut

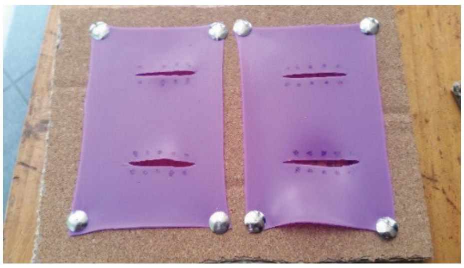
Cut only the top layer of the latex along the line drawn

Task 5: Suture Sponge

1. Drive the needle through the outside targets to the inside target from all four directions

2. Drive the needle from the far-left target, along the front and up to the far-right target

3. Go back along the path in step to end on the far-left target.



Task 6: Running suture

1. Drive needle across the gap through the first two targets and tight one surgeon's knot and 2 square knots

2. Drive the needle in a running pattern through subsequent pairs of targets

3. Anchor the suture by driving through the last pair of targets

Figure 4 Illustration of tasks with instructions for study participants using the surgical robot.

References

1. Intuitive Surgical, Inc. Annual Report 2016 [Internet]. 2016. Available from: http://www.annualreports.com/HostedData/AnnualReports/PDF/NASDAQ_ISRG_2016.pdf

2. Abboudi H, Khan M, Aboumarzouk O, Guru K, Challacombe B, Dasgupta P et al. Current status of validation for robotic surgery simulators - a systematic review. BJU Int. 2012;111(2):194-205.

3. Lanfranco A, Castellanos A, Desai J, Meyers W. Robotic Surgery. Ann Surg. 2004;239(1):14-21.

4. Sridhar A, Briggs T, Kelly J, Nathan S. Training in Robotic Surgery—an Overview. Curr Urol Rep. 2017;18(8):58.

5. Derossis A, Fried G, Abrahamowicz M, Sigman H, Barkun J, Meakins J. Development of a Model for Training and Evaluation of Laparoscopic Skills. Am J Surg. 1998;175(6):482-487.

6. Sroka G, Feldman L, Vassiliou M, Kaneva P, Fayez R, Fried G. Fundamentals of Laparoscopic Surgery simulator training to proficiency improves laparoscopic performance in the operating room—a randomized controlled trial. Am J Surg. 2010;199(1):115-120.

7. Goh A, Aghazadeh M, Mercado M, Hung A, Pan M, Desai M et al. Multi-Institutional Validation of Fundamental Inanimate Robotic Skills Tasks. J Urol. 2015;194(6):1751-1756.

8. Foell K, Finelli A, Yasufuku K, Bernardini M, Waddell T, Pace K et al. Robotic surgery basic skills training: Evaluation of a pilot multidisciplinary simulation-based curriculum. Can Urol Assoc J. 2013;7(11-12):430.

9. Siddiqui N, Galloway M, Geller E, Green I, Hur H, Langston K et al. Validity and Reliability of the Robotic Objective Structured Assessment of Technical Skills. Obstet Gynecol. 2014;123(6):1193-1199.

10. Smith R, Patel V, Satava R. Fundamentals of robotic surgery: a course of basic robotic surgery skills based upon a 14-society consensus template of outcomes measures and curriculum development. Int J Med Robot. 2013;10(3):379-384.

11. Dulan G, Rege R, Hogg D, Gilberg-Fisher K, Arain N, Tesfay S et al. Developing a comprehensive, proficiency-based training program for robotic surgery. Surgery. 2012;152(3):477-488.

12. Jarc A, Curet M. Construct validity of nine new inanimate exercises for robotic surgeon training using a standardized setup. Surg Endosc. 2013;28(2):648-656.

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