Robotic surgery basic skills training: Evaluation of a pilot multidisciplinary simulation-based curriculum

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Abstract

Purpose: Simulation-based training improves clinical skills, while minimizing the impact of the educational process on patient care. We present results of a pilot multidisciplinary, simulation-based robotic surgery basic skills training curriculum (BSTC) for robotic novices.

Methods: A 4-week, simulation-based, robotic surgery BSTC was offered to the Departments of Surgery and Obstetrics & Gynecology (ObGyn) at the University of Toronto. The course consisted of various instructional strategies: didactic lecture, self-directed online-training modules, introductory hands-on training with the da Vinci robot (dVR) (Intuitive Surgical Inc., Sunnyvale, CA), and dedicated training on the da Vinci Skills Simulator (Intuitive Surgical Inc., Sunnyvale, CA) (dVSS). A third of trainees participated in competency-based dVSS training, all others engaged in traditional time-based training. Pre- and post-course skill testing was conducted on the dVR using 2 standardized skill tasks: ring transfer (RT) and needle passing (NP). Retention of skills was assessed at 5 months post-BSTC.

Results: A total of 37 participants completed training. The mean task completion time and number of errors improved significantly post-course on both RT (180.6 vs. 107.4 sec, $p < 0.01$ and 3.5 vs. 1.3 sec, $p < 0.01$, respectively) and NP (197.1 vs. 154.1 sec, $p < 0.01$ and 4.5 vs. 1.8 sec, $p = 0.04$, respectively) tasks. No significant difference in performance was seen between specialties. Competency-based training was associated with significantly better post-course performance. The dVSS demonstrated excellent face validity.

Conclusions: The implementation of a pilot multidisciplinary, simulation-based robotic surgery BSTC revealed significantly improved basic robotic skills among novice trainees, regardless of specialty or level of training. Competency-based training was associated with significantly better acquisition of basic robotic skills.

Introduction

Since the platform was first introduced in 1999,[1,2] robotic surgery using the da Vinci Surgical System (Intuitive Surgical Inc., Sunnyvale, CA) has gained widespread adoption in surgical fields, such as urology and gynecology.[2,3] Recently, we have also seen increasing utilization in other specialties, such as otolaryngology, general and cardiothoracic surgery.[4] Improvements in surgical precision, dexterity, optics, as well as the ergonomic advantages of robotic surgery, have prompted surgeons to adopt this novel technology, more so than after the introduction of other surgical technologies (e.g., laparoscopy).[5] Despite the "intuitive" nature of robotic surgery, the integration of this innovative technology into clinical practice still requires appropriate training and is associated with a real learning curve.[6-9] Since robotic surgery, unlike traditional open or laparoscopic surgery, requires familiarity with a unique surgical interface, training is required not only for procedural, but robotic systems-based competencies as well.

Despite the need for comprehensive, structured training curricula, few validated robotic basic skills training curricula (BSTC) exist, particularly for specialties that have not fully embraced robotic surgery (e.g., cardiothoracic surgery) and within countries where the adoption of robotics is still in its relative infancy (e.g., Canada). To address this general gap, our group has begun to develop and implement a robotic surgery BSTC for robotic novices at our institution. Unlike in the United States, the adoption of robotic surgery in Canada has been much less widespread and its acceptance into clinical practice much less fervent. While robotic surgery is currently offered at a few of the hospitals affiliated with the University of Toronto, robotic surgery exposure has not reached the levels seen in most American training programs. We present a preliminary evaluation of our pilot multidisciplinary, simulation-based robotic surgery BSTC.

Methods

A 4-week robotic surgery BSTC was offered to residents, fellows, and staff surgeons at the University of Toronto, Departments of Surgery and Obstetrics and Gynecology (ObGyn). The curriculum consisted of various instructional strategies: didactic lecture, self-directed online-training modules, introductory hands-on training with the da Vinci robot (dVR), and dedicated, simulation-based training on the virtual reality da Vinci Surgical Simulator (dVSS).

All participants completed an initial survey detailing demographic and training-related information. The didactic and self-directed online training modules[10] focused on the cognitive objectives of the BSTC: benefits and limitations of robotic technology, review of the various robotic systems and standard equipment available for use, introductions to the patient cart, surgeon's console and vision cart, review of the principles of robot setup, trocar placement, docking, instrument exchange, clutching and troubleshooting of common technical problems.

Participants then engaged in several hands-on training sessions to address the skills objectives of the BSTC. Firstly, all participants were given a 2-hour standardized, hands-on introduction to the dVR, which included a review of its functionalities (including dedicated time to practice docking the dVR, camera setup and instrument exchange) and 30 minutes to practice basic robotic skills on inanimate models (endowrist and camera manipulation, instrument clutching, object manipulation, needle driving, suturing and knot tying). Three individual 1-hour sessions on the dVSS were then organized for each participant, at weekly intervals, during which each participant performed a standardized set of dVSS exercises addressing the following skills: camera navigation, instrument clutching, third arm functionality, endowrist manipulation of objects, needle handling and driving, cautery, and dissection.

Two-thirds of participants progressed through the dVSS simulated exercises in a traditional, time-based training model while one-third (urology group) were engaged in a competency-based dVSS curriculum. Using the built-in software scoring algorithm, participants achieved a 80% score before proceeding to the next exercise; moreover, immediate formative feedback from an expert robotic surgeon was provided after each exercise.

Pre- and post-course skills testing were conducted on the dVR using 2 standardized skill tasks with inanimate models: ring transfer (RT) and needle passing (NP). The RT task involved moving rings from a peg to 1 of 2 alternating pegs. The NP task involved driving a needle (RB-1) through a series of small rings, from one hand to the other. Performance assessment included time to completion and number of errors (i.e., dropped objects, collisions, excessive force, missed targets) for both tasks. A post-course survey was administered to all study participants.

The urology participants were reassessed 5 months after course completion, with repeat performance of the RT and NP tasks.

Statistical analysis was performed using Excel StatPlus (AnalystSoft Inc.). The pre- and post-course skills results were compared using a 2-tailed paired student's t-test. For nonparametric variables, the Mann Whitney U test was used for independent samples, and the Wilcoxon matched pairs test for related samples. Results between specialties were compared using ANOVA. A *p* value <0.05 was considered significant for all tests.

Results

In total, 37 participants completed the robotic surgery BSTC: 13 urology, 12 ObGyn and 12 thoracic surgery (Table 1). Participants' level of training ranged from junior resident to staff surgeon. Of the participants, 22 (59.5%) had no clinical robotic experience whatsoever, and 30 (81.1%) had no robotic console experience. Despite limited previous console experience, all participants self-identified as robotic novices.

Table 1. Robotic surgery BSTC participant demographic data

Survey question	Response	No. (%)
Gender	Male	24 (64.9)
	Female	13 (35.1)
Handedness	Right-hand dominant	31 (83.8)
	Left-hand dominant	3 (8.1)
	Ambidextrous	3 (8.1)
Level of training	Junior resident (R1-R3)	7 (18.9)
	Senior resident (R4-R5)	12 (32.4)
	Fellow	15 (40.5)
	Staff surgeon	3 (81)
Specialty	Urology	13 (35.1)
	ObGyn	12 (32.4)
	Thoracics	12 (32.4)
Previous MIS-laparoscopic/ thoracoscopic	None/minimal	8 (21.6)
	Moderate	11 (29.7)
	Significant	15 (40.5)
	Fellowship-trained in MIS	3 (8.1)
Previous robotic surgery experience	None	22 (59.5)
	Yes	15 (40.5)
If yes, no. operative cases as surgical assistant	0 cases	0 (0)
	<10 cases	9 (60)
	10-20 cases	3 (20)
	>20 cases	3 (20)
If yes, no. operative cases at robotic console for at least 30 minutes	0 cases	8 (53.3)
	<10 cases	6 (40)
	10-20 cases	0 (0)
	>20 cases	1 (6.7)

MIS: minimally invasive surgery; BSTC: basic skills training curriculum.

The dVSS demonstrated excellent face validity, as all trainees felt the dVSS exercises looked realistic. Most participants (88%) felt that the dVSS was as effective as using the dVR with inanimate models for robotic surgery basic skills training.

While all 37 participants completed the BSTC, only 14 (37.8%) completed both pre- and post-course standardized skills tasks on the dVR; this was due to participant availability. The mean times and number of errors, both pre- and post-course, did not differ between the specialties. Overall, the participants demonstrated significantly improved mean times to completion and number of errors, post-course, for both tasks ($p < 0.01$) (Table 2). Previous robotic experience did not affect the results, as even the participants with some robotic experience demonstrated significant improvements. Neither level of surgical nor minimally-invasive surgery training significantly affected the results.

While both the competency-based dVSS curriculum participants and traditional, time-based curriculum participants demonstrated significant improvements post-BSTC, the competency-based training group demonstrated better skill acquisition than the time-based training group (Table 3). At baseline, pre-BSTC testing, the proficiency-based group demonstrated a higher number of errors on both tasks, but similar times for task completion when compared to the time-based training group.

Among the participants that were assessed 5 months after the BSTC, the improvements were durable for RT and NP time. There was a significant increase in RT errors and a trend towards increased NP errors (Table 4).

Table 2. Performance parameters for participants completing both pre- and post-course standardized robotic tasks

Task	Parameter	Pre-course	Post-course	*p* value
RT	Time (mean ± SD)	180.6 ± 58.2 s	107.4 ± 32.8 sec	<0.001
	Number of errors (mean ± SD)	3.5 ± 2.4	1.3 ± 1.1	0.006
NP	Time (mean ± SD)	197.1 ± 45.2 s	153.9 ± 45.2 sec	0.005
	Number of errors (mean ± SD)	4.5 ± 3.5	1.8 ± 1.8	0.005

RT: ring transfer; NP: needle passing; SD: standard deviation.

Discussion

Despite the rapid adoption of robotic surgery in clinical practice,[4,11] comprehensive training for the waves of novice robotic surgeons emerging from surgical training programs has often been inadequate. Most programs lack a validated robotic surgery training curriculum, in large part due to a lack of widespread robotic expertise. As many faculty members are going through their own robotic surgery learning curves, the downstream effect results in limited exposure and a lack of formal, structured curricula for today's trainees. This is particularly true in Canada where robotic surgery has not seen the rate of diffusion as in the United States.

For post-graduate surgeons looking to adopt robotic surgery, most available BSTC are industry-led rather than being designed by robotic surgery content experts, and usually involve a short 1-day training session that lacks any formal assessment of competency. The process of robotic surgery certification lacks consensus or consistency across jurisdictions[4,12,13] and often lacks a true assessment of individual competency. In certain regions of the world, such as Canada, where the integration of robotic surgery into clinical practice is still in its early stages, the lack of formal robotic surgery training opportunities, for trainees and faculty, is even more profound.

Others have also noted this lack of structured training and have commented on the need to develop more comprehensive, validated training and credentialing programs.[13] To address this need, several groups have begun the process of developing and validating robotic surgery training curricula. At the University of California Irvine, the short- and long-term benefits of procedure-specific 5-day robotic surgery training courses have been reported.[14,15] More recently, educators at the University of Texas Southwestern have published feasibility, validity, and reliability data on a competency-based inanimate training program for robotic surgery, which also addresses the need for structured training programs.[16]

Surgical training literature has clearly demonstrated the superior educational outcomes associated with curricula that adhere to the principles of spaced-learning and competency-based training.[17-20] The utilization of virtual reality simulation-based training strategies to minimize the footprint of surgical training and associated learning curves has also gained momentum and acceptance. By providing an opportunity for low-stakes, deliberate practice,[21] simulation-based training allows surgeons to work through the early parts of their learning curve outside of the clinical care setting, thereby optimizing patient care.[13,17] As such, simulation-based training is likely to have an increasing role in all future surgical education initiatives, regardless of discipline.

Preliminary evaluation of our pilot multidisciplinary, simulation-based robotic surgery BSTC demonstrates a clear educational benefit, regardless of surgical specialty, level of training, or previous robotic experience; overall post-course performance metrics revealed a significant improvement among our participants. These improvements were seen in the laboratory setting only and, as such, further research is required to examine the impact on performance in the clinical setting. This ability to demonstrate the clinical benefits of simulation-based training on patient care is the crux of the debate on the role of surgical simulation in today's training

Table 3. Post-BSTC testing results for competency- vs. time-based dVSS training

Timing	Parameter	Competency-based dVSS training**	Time-based dVSS training	*p* value
Pre-BSTC	RT time (mean ± SD)	157.5 ± 40.5 s	198.0 ± 65.7 s	0.181
	RT errors (mean)	5.0	2.4	0.045
	NP time (mean ± SD)	188.7 ± 39.9 s	203.4 ± 50.6 s	0.554
	NP errors (mean)	6.7	2.9	0.039
Post-BSTC	RT time (mean ± SD)	87.0 ± 13.3 s	122.8 ± 35.3 s	0.022
	RT errors (mean)	1.0	1.5	0.651
	NP time (mean ± SD)	132.5 ± 22.3 s	170.0 ± 35.9 s	0.034
	NP errors (mean)	2.8	1.0	0.053

BSTC: basic skills training curriculum; RT: ring transfer; NP: needle passing; SD: standard deviation. dVSS: da Vinci Skills Simulator (Intuitive Surgical, Sunnyvale, CA).
**Competency-based group was either equivalent or worse than Time-based group on all pre-BSTC parameters.

Table 4. Performance parameters for participants repeating the standardized robotic tasks five months after BSTC, who also completed pre- and post-curriculum (n=6)

Metric	Immediately post-BSTC	5 months post-BSTC	*p* value
RT time (mean ± SD)	87.0 ± 13.3 s	64.5 ± 16.0 s	0.008
RT errors (mean)	1.0	3.0	0.043
NP time (mean ± SD)	132.5 ± 22.3 s	136.2 ± 26.1 s	0.566
NP errors (mean)	2.8	4.3	0.075

BSTC: basic skills training curriculum; RT: ring transfer; NP: needle passing; SD: standard deviation.

paradigm. With increasing use of simulation-based training strategies, clear evidence that demonstrates its clinical value is beginning to emerge.[18,19,22-24]

In our preliminary evaluation, trainees completing either the competency-based or traditional time-based training curriculum demonstrated improvements post-BSTC. These preliminary results suggest greater improvements using competency-based training, particularly with time to task completion, and warrant further evaluation. While most training curricula lack this framework, in part due to personnel and financial resource limitations, the value of competency-based training has become a central tenet within the surgical education community.[17,25]

Our simulation-based training curriculum used the dVSS, a previously validated virtual reality surgical simulator.[26-29] The dVSS had excellent face validity and was rated by 88% of participants as effective as the dVR itself for basic skills training. Unlike other robotic surgery simulators, the dVSS combines the actual dVR surgeon console with proprietary, validated training software (Mimic Technologies, Seattle, WA); this improved the fidelity of the simulation significantly and perhaps added to its educational benefit.

This study has several limitations. The results are from a pilot study, and require further validation in a larger cohort of participants. Though all participants completed the curriculum, the rate of participation in both pre- and post-BSTC standardized skills tasks was low (37.8%); this could have introduced selection bias if participants not benefitting from the BSTC were dis-inclined to undergo post-BSTC testing. Though performance improved on 2 standardized, robotic skills tasks, it has yet to be demonstrated that the BSTC contributes to improved clinical performance. While the improvement in time for task completion appears durable after 5 months, there was a decline in performance with respect to number of errors. However, this was in a limited number of subjects and warrants further evaluation. Also, our initial evaluation has demonstrated improvements in technical skill; however, acquisition and retention of cognitive learning objectives were not fully assessed. Finally, RT and NP performance skills relied on a single faculty rater, so further reliability evidence is required for this curriculum.

Conclusion

Preliminary evaluation of a 4-week, multidisciplinary, simulation-based robotic surgery BSTC demonstrates improved robotic surgical skills among robotic trainees, regardless of specialty, previous robotic experience, and level of training. Competency-based training was associated with better post-course performance compared to traditional time-based training, though there were improvements in performance with both types of training. Further validation studies are required and it is imperative that we ultimately determine the impact of such simulation-based training curricula on clinical performance.

Competing interests: Dr. Pace is a member of an Advisory Board for Janssen and Amgen. He has also received support for a fellowship from Cook Medical. Dr. Finelli is Advisory Board member for Amgen, Astellas and Janssen. He has also received honoraria from Amgen, Astellas, Janssen, Paladin and Astra Zeneca. Dr. Finelli has also participated in clinical trials in the past 2 years for Amgen, Astellas, Janssen and Ferring. Dr. Foell has recieved an honorarium from Actavis. Dr. Honey is currently involved in an outcome study in shock wave lithotripsy. Dr. Lee hs received honoraria from Takeda Inc. Dr. Yasufuku, Dr. Bernardini and Dr. Waddell declare no competing financial or personal interests.

This paper has been peer-reviewed.

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