Surgical Cross-Training With Surgery Naive Learners: Implications for Resident Training

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OBJECTIVE: While current literature has explored the transferability of laparoscopic surgical skills to robotic surgery, this study looks to investigate the transferability of surgical skills between robotic surgical simulation and simulated traditional laparoscopy.

DESIGN: Participants completed a survey regarding prior surgery exposure and other confounding factors including previous video game experience and self-assessed hand-eye coordination. Following orientation to the laparoscopic simulator (LS) and robotic surgical simulator (RoSS), participants were timed performing the Balloon Grasp and Ball Drop tasks on the RoSS and the Peg Transfer and Ball Drop tasks on the LS. Participants were then randomized to either the laparoscopic or RoSS arm and timed performing the Ball Drop task 10 times and then reassessed performing the Ball Drop using the unpracticed modality.

SETTING: Clinical Simulation Laboratory at the University of Vermont

PARTICIPANTS: A total of 31 medical students with limited experience in laparoscopic and robotic surgery.

RESULTS: There were no statistically significant differences in the demographics or prior surgical and videogame experience between the participants in the laparoscopic and robotic arms of the study ($X^2 = 0.72$, $p = 0.75$). Timed initial assessment of the RoSS Balloon Grasp ($p = 0.84$) and Ball Drop ($p = 0.79$) tasks and the LS Peg Transfer ($p = 0.14$) and Ball Drop ($p = 0.44$) tasks were not statistically different between the 2 arms. The simulator modality which was practiced yielded the greatest improvement. The degree of improvement on the unpracticed modality was not statistically different between the groups ($p = 0.57$), and it was not significantly better than 2 rounds of sequential practice on the practiced modality (LS, $p = 0.98$ and RoSS, $p = 0.55$).

CONCLUSIONS: With practice, both groups increased surgical skill on the unpracticed modality. However, this degree of improvement was equal, suggesting there is no transferability of skills between laparoscopy and robotics. (J Surg Ed 76:1469–1475. © 2019 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: robotics, laparoscopy, simulation, resident, medical student

COMPETENCIES: Patient Care, Practice-Based Learning and Improvement, Systems-Based Practice

INTRODUCTION

Across surgical subspecialties and obstetrics and gynecology, laparoscopic and robotic surgical techniques comprise the realm of minimally invasive surgery which has transformed the landscape of surgical practice. From George Kelling's first attempted laparoscopy in 1901 to the widespread adaptation of laparoscopic surgical interventions in gynecology throughout the 1960s and 1970s, laparoscopic surgery has become a fundamental

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technique in the surgeon's toolbox, constructing the foundation for the explosive growth of the minimally invasive surgical field.[1] More recently, robotic surgery has emerged as a tool to augment minimally invasive surgery. Since the first implementation of the da Vinci Surgical System (dvSS) for endoscopic coronary artery bypass grafting by Intuitive Surgical Inc. (Sunnyvale, California) in 1999, the use of robotic surgical techniques has increased exponentially in practice and has expanded its use to a multitude of surgical subspecialties including urology and gynecology.[2] These minimally invasive techniques have grown in popularity, offering patients the benefits of shorter hospitalization times, quicker recovery times, decreased operating times, and decreased estimated blood loss.[3-7]

With the increased implementation of traditional laparoscopy and robotic technology, it is becoming increasingly common for residents in surgical fields to receive some degree of minimally invasive surgical skills training via a laparoscopic simulator (LS) and/or a robotic simulator [ex. Robotic Surgical Simulator (RoSS)]. To address the learning curve associated with the adoption of robotic surgery, the RoSS was developed as a virtual reality RoSS with face, content, and construct validity.[8] Face validity refers to the relative realism of the simulator as determined by nonexperts.[8] Content validity is determined by experts and describes the extent to which the simulator is able to successfully teach trainees the intended skill.[8] Construct validity describes the extent to which the simulator can identify the skill level, novice vs expert, of users based on performance during simulated tasks.[8]

Recent literature supports that training on a LS or RoSS improves surgical performance on the robotic dVSS used in operating rooms across the world.[9-13] Within the literature, debate has arisen regarding the benefit of laparoscopic experience on robotic surgery performance. It has been hypothesized that the transferability of laparoscopic skills to robotic surgery may be limited to situations that rely upon surgical skills expertise such as knot tying.[13] Conversely, other studies have demonstrated that formal laparoscopic training did improve robotic surgical techniques although there was significant variation in the extent of this effect.[9,13] While not universally accepted, the majority of studies comparing the learning curves for laparoscopic and robotic surgical training identified a shorter learning curve for robotic surgery.[9,14-16] However; to the best of our knowledge, no group has evaluated the corollary, whether training on the RoSS or the dVSS improves traditional laparoscopic skills. With the potentially shorter learning curve for robotic surgery, it highlights the benefit of training residents first on robotic simulators like the RoSS if these skills are transferable to traditional laparoscopy. If the RoSS could serve a transferable dual function of training residents in both modalities, this could transform the landscape of resident education, especially given the current climate of American Council for Graduate Medical Education (ACGME) duty-hour restrictions, Medicare-dictated performance-based reimbursement, and rapid technological advancements.

We sought to investigate the transferability of surgical skills by evaluating if surgical simulation training in robotics modified performance in simulated traditional laparoscopy.

METHODS

Study Design

Due to the educational nature of this project, it was granted exempt status by the University of Vermont Institutional Review Board (IRB). Thirty-one medical students from the University of Vermont College of Medicine, first competed a survey regarding prior surgery exposure and other confounding factors including previous video game experience and self-assessed hand-eye coordination. After watching an introductory video (https://www.youtube.com/watch?v=seUeTeSyxHc) that details the 4 tasks, the students were oriented to both the low-fidelity LS (KARL STORZ GmbH & Co. KG, Tuttlingen, Germany) and the high-fidelity RoSS (Simulated Surgical Systems; Williamsville, New York).[17,18] On the RoSS, participants were timed performing the Balloon Grasp and Ball Drop tasks, while on the LS, they were timed performing the Peg Transfer and Ball Drop. On the RoSS, the Balloon Grasp task requires participants to grasp a virtual balloon to deflate it, alternating between using the grasper with the dominant and nondominant hands, with the purpose of orienting participants to the visual field and the tactile movements needed to operate the RoSS. For both the RoSS and LS modalities, the Ball Drop task involves picking up balls and placing them onto a tray, designed to develop precise instrument control skills.[19] The Peg Transfer task on the LS system is 1 of the 5 required tasks on the Fundamentals of Laparoscopic Surgery (FLS) exam and serves to evaluate bimanual coordination.[20,21] It involves grasping each peg with a Maryland dissector in the participant's nondominant hand and transferring pegs to a grasper in the dominant hand and placing the peg on the opposite side of the pegboard. Once all 6 pegs are transferred, the process is reversed. Participants were randomized to either the LS or RoSS arm of the study and timed performing the Ball Drop task 10 times on their assigned simulator modality; students were then

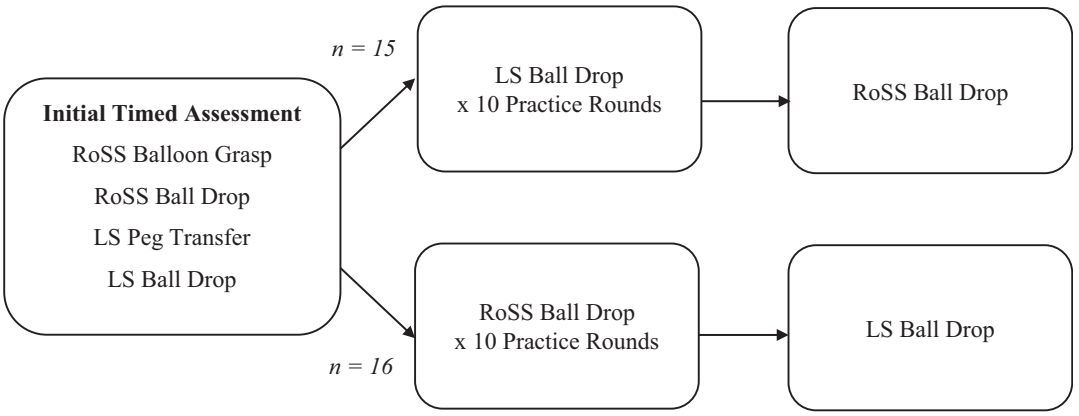

FIGURE 1. Flow diagram depicting study design.

reassessed performing the same task on the modality on which they had not trained (Fig. 1).

Statistical Analysis

A power analysis of preliminary pilot data from a small subset of medical students ($\alpha = 0.05$; $\beta = 0.2$) revealed that, utilizing a paired *t* test, 20 subjects would be needed to detect a 20-second improvement in the LS Ball Drop when practicing on the RoSS, assuming a standard deviation of 30 seconds within the groups. There is little or no data to support if a 20-second improvement is clinically significant as most studies do not evaluate data outside of simulated setting and most studies use residents and fellows, rather than medical students as the study population. To compare participant characteristics, a chi-square test or a Fisher's exact test was used for statistical analysis. *t* tests for equality of means were used to analyze the baseline assessment of the laparoscopic and robotic skills between the 2 study arms. Paired *t* test analysis was conducted to detect differences in each arm's improvement in mean performance by modality. Improvement curves for each modality during practice rounds was determined via repeated measures ANOVA.

RESULTS

Study Participant Demographics

Table 1 summarizes the demographic data of the participants in the laparoscopic and robotic arms of the study. There were no statistically significant differences in sex, handedness, age, or experiential confounding factors including prior laparoscopic experience, robotic experience, videogame experience, or self-rated eye-hand coordination between the study arms ($X^2 = 0.72$, $p = 0.75$).

Baseline Simulator Assessment

The performance times to complete each of the initial assessment tasks were similar between the LS and RoSS arms of the study, indicating a similar baseline in skill level among participants (Table 2). Timed initial assessment of the RoSS Balloon Grasp ($p = 0.84$) and RoSS Ball Drop ($p = 0.79$) tasks and the LS Peg Transfer ($p = 0.14$) and LS Ball Drop ($p = 0.44$) tasks did not differ statistically significant between the 2 study arms.

TABLE 1. Demographic Data of Participants From Self-Reported Survey (n = 31)

Characteristic	RoSS	LS	P value
Gender			0.61
Female	11	9	
Male	5	6	
Right handed	15	13	0.50
Average age (y.o.)	27.19	27.47	0.80
Laparoscopic experience			0.34
None	6	4	
<1 h	5	8	
1-5 h	5	2	
5-10 h	0	1	
>10 h	0	0	
Robotic experience			0.89
None	10	9	
<1 h	6	6	
Video game experience			0.56
None	7	3	
Beginner	4	5	
Intermediate	4	6	
Advanced	1	1	
Hand-eye coordination (self-assessment)			0.89
Poor	3	2	
Moderate	6	5	
Good	6	6	
Excellent	1	2	

TABLE 2. Assessment of Baseline Laparoscopic and Robotic Skills of Participants, Who Were Timed Performing Balloon Grasp and Ball Drop Tasks on the RoSS and Peg Transfer and Ball Drop Tasks on the Laparoscopic Simulator

Task	LS Arm Mean Time (s)	RoSS Arm Mean Time (s)	p Value
Balloon Grasp: RoSS	57	56	0.84
Ball Drop: RoSS	222	215	0.79
Peg Transfer: LS	194.2	243.9	0.14
Ball Drop: LS	84.3	90.5	0.44

The starting skill level was not statistically different between the 2 arms of the trial on the initial assessment (IA) of all 4 tasks. (*t* tests for equality of means).

Simulator Assessment on Practiced Modality

In both arms, 10 practice rounds of the Ball Drop task resulted in improved performance on the practiced modality (Table 3). During the practice rounds, the LS arm demonstrated improvement in performance time in a linear fashion with increasing number of practice rounds, while the RoSS arm task performance improved along a more quadratic line function (Fig. 2). These learning curves did not culminate in a plateau, which would have indicated that the participants reached steady state in their training, and therefore, infers that participants did not achieve a mastery skill level within the confines of the 10 practice rounds. The greatest improvement in performance time was observed on the simulator modality that the practice rounds were completed on.

Simulator Assessment on Unpracticed Modality

Both the LS and RoSS groups improved on the opposite modality (Table 3; Figs. 1 and 2). The degree of improvement on the opposite modality was equal, suggesting no difference in the transferability of skills between laparoscopy and robotics. The degree of improvement on the unpracticed modality was not statistically different between the groups ($p = 0.57$) and was not significantly better than 2 rounds of sequential practice on the practiced modality (LS, $p = 0.98$ and RoSS, $p = 0.55$). Together this suggests that there is no transferability of skills between laparoscopy and robotics within our study parameters (Fig. 3).

DISCUSSION

Traditional laparoscopy and robotic surgery compose the broad realm of minimally invasive surgical modalities in practice today. With the ACGME duty hour restrictions, Medicare-dictated performance-based reimbursement, and rapid technology advancements, a new challenge of training surgeons in the clinical environment has emerged. Thus, surgical curriculum development using virtual reality simulators and other surgical platforms to effectively train surgeons outside the operating room is an area of active investigation. With limited time and resources, it is becoming exceedingly important to identify the most effective, efficient, and safest means to train surgeons. Identifying, validating, and implementing skills tests, surgical trainers, and surgical curriculums that may be transferable across surgical modalities and allow us to "cross-train" learners may provide a solution to this challenging problem.

In agreement with the current literature, this study's findings demonstrated an improvement in learner skills with simulator practice sessions on the RoSS and LS modalities.[14,16,22] Moreover, the observation of linear improvement in laparoscopic skills as opposed to the quadratic improvement for robotic skills mirrored previously published data.[16] This finding implies that learning via the LS modality occurs in a more constant, steady rate with consistent improvement over time. However, in accordance with the current literature, this study also identified the robotic skills improved in a quadratic fashion, indicating that the rate of improvement increases with time. Debate has arisen within the current literature whether laparoscopic training improves robotic skills. Within the studies that identified an improvement in robotic simulation exercises after laparoscopic training, the extent of this effect has been quite variable with some studies demonstrating a slight positive effect.[9,13]

TABLE 3. Improvement in Mean Performance by Modality (LS vs RoSS)

	LS Arm Mean Time Improvement (%)	RoSS Arm Mean Time Improvement (%)	Practice 1 Mean Time Improvement (%)
Practice: LS	52.4	23.4	17.8
Practice: RoSS	17.9	61.1	15.8

Modalities which were practiced demonstrated the largest percentage of improvement.

The degree of improvement on the unpracticed modality was not statistically different between the 2 groups (*t* test, $p = 0.57$), and it was not significantly better than 2 rounds of sequential practice (*t* test, LS, $p = 0.98$ and RoSS, $p = 0.55$).

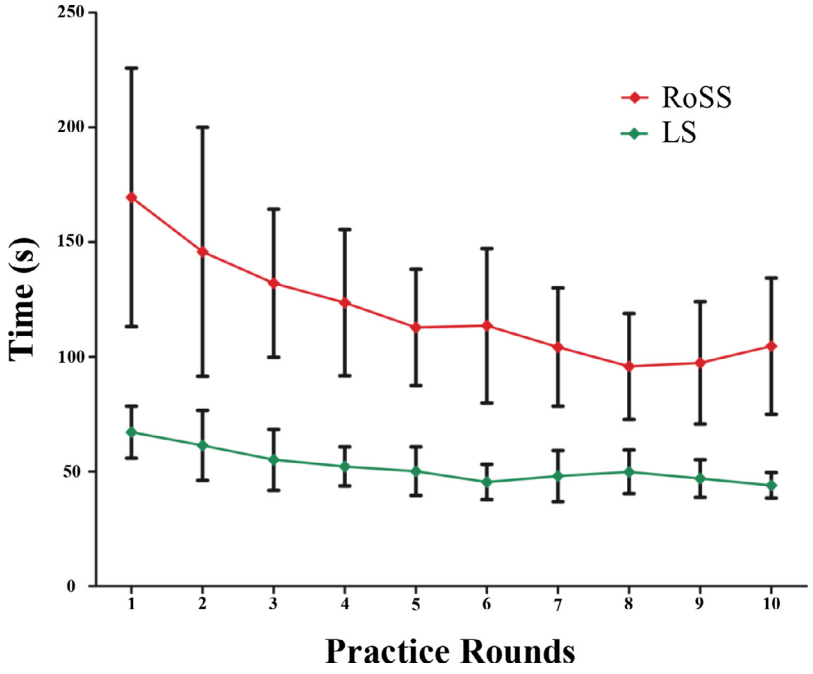

FIGURE 2. Comparing trends in mean performance time on ball drop task during 10 practice rounds between LS and RoSS modalities.

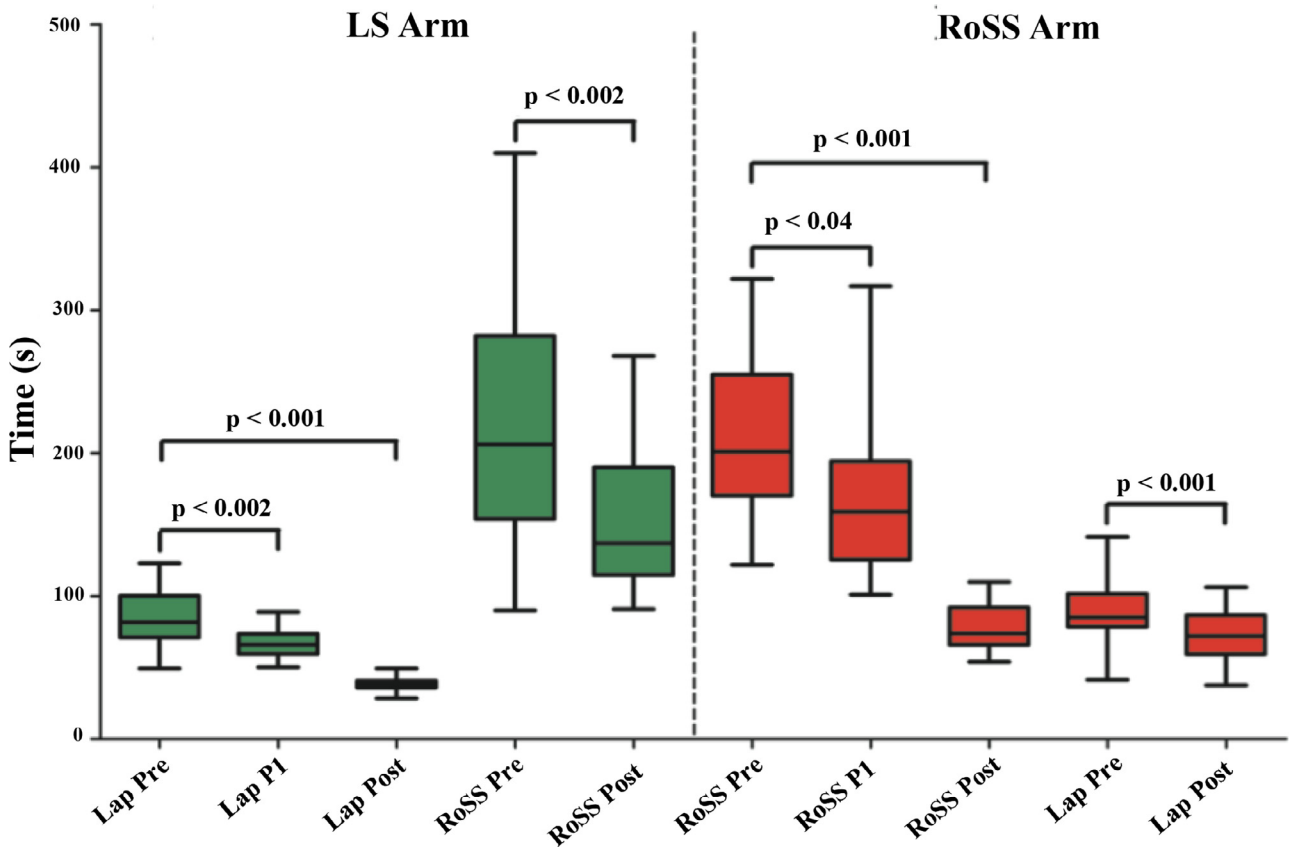

FIGURE 3. Comparison of absolute task performance time differences after practice between the LS and RoSS arm.

However, Tillou et al. found that study participants' prior experience with traditional laparoscopy impacted their performance on the robotic simulator tasks as more experienced laparoscopic surgeons were impeded by their expertise and had to "unlearn" to acquire the new skills needed for the robotic simulation.[23] This study observed no significant difference in the RoSS arm-assigned participants' performance on the LS after robotic simulation training sessions, demonstrating the variability in the transferability of robotic to laparoscopic simulation tasks.

Alternatively, within the current literature, no studies exist demonstrating that robotic training improves laparoscopic skills. One prior study by Orlando et al. showed no difference in performance between laparoscopic and robotic training groups on a robotic simulation task.[22] Thus, the hypothesis that robotic simulation training could bestow skills transferable to traditional laparoscopy and vice versa motivated this study. However, the study findings failed to demonstrate that there is transferability between robotics and laparoscopy. In this study, performance time on the unpracticed modality improved equally between the 2 study arms. Moreover, the degree of improvement on the unpracticed modality was not significantly better than 2 rounds of sequential practice. Based on the study parameters, together these findings suggest that there is no difference in the transferability of skills between laparoscopy and robotics. This study does support the need to develop 2 separate surgical curricula, 1 in laparoscopy and 1 in robotic surgery, to train naive learners in both modalities, which will require more thoughtful and evidence-based research to effectively train the future generation of surgeons. Moreover, it suggests that as technology increases, if training is not transferable, then residents are required to learn more skills in the same amount of time as their historical peers. Thus, in order to produce resident graduates that are competent at the time of graduation, certain residency programs like surgery and ObGyn may need to lengthen the training, or track residents into surgical subspecialties, or eliminate unnecessary portions of training from the curricula.

In response to the increasing demand to educate residents in minimally invasive techniques, new curricula have been developed to address this evolving landscape in the surgical world. The Fundamentals of Laparoscopy has emerged as the gold standard for traditional laparoscopic education, backed by evidence supporting the transferability of simulation to the operating room for traditional laparoscopy.[24,25] In fact, since 2008, the American Board of Surgery has required successful completion of FLS as a requirement for general surgery board certification.[26] Similar efforts have been made to replicate the success of FLS for the growing field of robotic surgery. With the validation of the Fundamentals of Robotic Surgery by the American College of Surgeons and the Robotic Training Network, new instructional models are being developed to address the need for resident and faculty education in the evolving field of robotic surgery.[27] While these training efforts provided simulation as a means to enhance surgical skills in the ACGME hour restricted work environment, an optimal solution to training residents in minimally invasive surgical techniques has yet to be realized; a curriculum based in experiential learning that is transferable between the modalities of laparoscopy and robotic surgery to provide a more efficient, targeted resident education experience. While this study failed to demonstrate transferability between the RoSS training modality and laparoscopic simulation, it is critical to continue to investigate how best to conduct surgical simulation instruction to effectively cross-train residents in robotic and laparoscopic techniques which have become increasingly prevalent in surgical practice across a diversity of subspecialty fields.

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