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Comparison of precision and speed in laparoscopic and robot-assisted surgical task performance

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ABSTRACT

Background: Robotic platforms have the potential advantage of providing additional dexterity and precision to surgeons while performing complex laparoscopic tasks, especially for those in training. Few quantitative evaluations of surgical task performance comparing laparoscopic and robotic platforms among surgeons of varying experience levels have been done. We compared measures of quality and efficiency of Fundamentals of Laparoscopic Surgery task performance on these platforms in novices and experienced laparoscopic and robotic surgeons.
Methods: Fourteen novices, 12 expert laparoscopic surgeons (>100 laparoscopic procedures performed, no robotics experience), and five expert robotic surgeons (>25 robotic procedures performed) performed three Fundamentals of Laparoscopic Surgery tasks on both laparoscopic and robotic platforms: peg transfer (PT), pattern cutting (PC), and intracorporeal suturing. All tasks were repeated three times by each subject on each platform in a randomized order. Mean completion times and mean errors per trial (EPT) were calculated for each task on both platforms. Results were compared using Student's *t*-test ($P < 0.05$ considered statistically significant).
Results: Among novices, greater errors were noted during laparoscopic PC (Lap 2.21 *versus* Robot 0.88 EPT, $P < 0.001$). Among expert laparoscopists, greater errors were noted during laparoscopic PT compared with robotic (PT: Lap 0.14 *versus* Robot 0.00 EPT, $P = 0.04$). Among expert robotic surgeons, greater errors were noted during laparoscopic PC compared with robotic (Lap 0.80 *versus* Robot 0.13 EPT, $P = 0.02$). Among expert laparoscopists, task performance was slower on the robotic platform compared with laparoscopy. In comparisons of expert laparoscopists performing tasks on the laparoscopic platform and expert robotic surgeons performing tasks on the robotic platform, expert robotic surgeons demonstrated fewer errors during the PC task ($P = 0.009$).
Conclusions: Robotic assistance provided a reduction in errors at all experience levels for some laparoscopic tasks, but no benefit in the speed of task performance. Robotic assistance may provide some benefit in precision of surgical task performance.

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Introduction

Robot-assisted laparoscopic surgery has been adopted in a variety of surgical fields.[1] Commonly used robotic surgical platforms are equipped with a variety of technologies that may improve the precision and efficiency of complex surgical task performance compared with traditional laparoscopic surgery.[2-6] Robotic platforms use wristed instruments that provide surgeons with additional degrees of freedom in performing surgical tasks compared with rigid laparoscopic instrumentation. Commonly used robotic platforms are usually paired with a high-definition three-dimensional camera that allows for improved precision and visualization of surgical targets when compared with two-dimensional camera platforms.[2-4] The surgeon's console allows for scalability of a robotic surgeon's movements to potentially allow for finer movement at the instrument tip than traditional laparoscopic instrumentation can provide.

However, the platform has technical limitations that may hinder task performance. Robotic platforms do not provide an operating surgeon with the haptic feedback that is transmitted through the shaft of a rigid instrument during laparoscopic task performance. In addition, most robot-assisted surgical platforms restrict surgical activity to one quadrant of a body cavity; however, the latest robotic platforms are equipped for multi-quadrant surgery.[5] Finally, robotic surgery is associated with a learning curve and is newer than traditional laparoscopic surgery. Surgeons less familiar with robotic surgery than traditional laparoscopy may experience poorer initial robotic task performance as a result of this learning curve. As the volume of robot-assisted surgery continues to increase, it is becoming more important to identify benefits or hindrances of the platform in comparison to other techniques.

To date, there have been few comparative evaluations of task performance on robotic and laparoscopic platforms. Preliminary reports have been equivocal thus far. In a study of suturing tasks performed by 20 novices and nine expert laparoscopic and robotic surgeons, novices appeared to benefit from robotic assistance in all measures of task performance quality, whereas experts benefited from robotic assistance only in economy of motion.[6] A study of novice surgeons performing a suturing task in a porcine model showed improvements in both task quality and subjective preference for the robotic platform.[7] A large study of 117 surgeons, primarily made up of expert laparoscopists, showed better task performance scores on the laparoscopic platform during a suturing task, whereas most participants subjectively considered the robotic platform to be easier and preferable to them.[8]

Most studies to date have been performed in a dry laboratory setting and have used tasks derived from the Fundamentals of Laparoscopic Surgery (FLS) curriculum to test performance quality, creating a common methodological framework.[6,8-10] Few reports, however, have examined surgeons across the spectrum of laparoscopic and robotic experience, including surgical novices, experienced laparoscopic surgeons with little robotic experience, and experienced robotic surgeons. In this study, we sought to use FLS tasks to evaluate differences in task performance quality and completion time between tasks performed on laparoscopic and robotic platforms across the spectrum of surgical experience. We hypothesized that a quantifiable improvement in task precision and speed associated with robotic compared with laparoscopic FLS task performance would be noted at all experience levels.

Methods

Power analysis

A power analysis was performed to determine the necessary sample size for each group. The expected effect size was set at 20% for the outcome measures studied; the standard deviation was estimated at ±25% from the mean; an alpha 0.05 and a power of 0.8 were used. These parameters yielded a sample size of 13 subjects per group.

Subject recruitment

Under an institutional review board–approved protocol #201101766, 31 subjects with varying levels of surgical experience were recruited for participation and informed consent was obtained in this study at Washington University in St. Louis. The following groups were recruited from multiple departments at Washington University in St. Louis: surgical novices (medical students, junior general surgery residents, $n = 14$); expert laparoscopic surgeons (senior general surgery residents, fellows, and attendings, >100 laparoscopic cases performed, no robotic experience, $n = 12$); and expert robotic surgeons (attendings in minimally invasive surgery, colorectal surgery, and urology, >25 robotic cases performed, $n = 5$). All expert laparoscopic surgeons had no prior robotic experience. All expert robotic surgeons were also expert laparoscopic surgeons. The study was performed in a laboratory equipped with a standard laparoscopic trainer setup including a laparoscopic trainer box (Karl Storz Endoscopy America, Incorporated, Culver City, CA) positioned on a table, a standard 10-mm 30-degree laparoscope (Karl Storz Endoscopy America, Incorporated), and laparoscopic instruments including needle drivers and disposable graspers, and scissors. The laboratory was also equipped with a standard da Vinci S Surgical System (dVSS Intuitive Surgical, Incorporated, Sunnyvale, CA) attached to a trainer box and two surgical arms equipped with needle drivers, graspers, and scissors. A height-adjustable chair was provided for the dVSS platform. All subjects without robotic experience received a 20-min introductory session on operating the dVSS console before beginning the study. All subjects without significant laparoscopic experience received a 20-min introductory session before beginning the study.

Task performance

Each subject performed FLS peg transfer, pattern cutting, and intracorporeal suturing tasks in standard fashion according to FLS protocol.[11] All subjects were individually given identical in-person 20-min introductions to the platforms and tasks and a 20-min opportunity for hands-on familiarization with the equipment before task performance. These tasks did not require clutching when performed on the da Vinci System.