The da Vinci Robot System Eliminates Multispecialty Surgical Trainees' Hand Dominance in Open and Robotic Surgical Settings

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ABSTRACT

Background and Objectives: Handedness, or the inherent dominance of one hand's dexterity over the other's, is a factor in open surgery but has an unknown importance in robot-assisted surgery. We sought to examine whether the robotic surgery platform could eliminate the effect of inherent hand preference.

Methods: Residents from the Urology and Obstetrics/Gynecology departments were enrolled. Ambidextrous and left-handed subjects were excluded. After completing a questionnaire, subjects performed three tasks modified from the *Fundamentals of Laparoscopic Surgery* curriculum. Tasks were performed by hand and then with the da Vinci robotic surgical system (Intuitive Surgical, Sunnyvale, California). Participants were randomized to begin with using either the left or the right hand, and then switch. Left:right ratios were calculated from scores based on time to task completion. Linear regression analysis was used to determine the significance of the impact of surgical technique on hand dominance.

Results: Ten subjects were enrolled. The mean difference in raw score performance between the right and left hands was 12.5 seconds for open tasks and 8 seconds for robotic tasks ($P < .05$). Overall left-right ratios were found to be 1.45 versus 1.12 for the open and robot tasks, respectively ($P < .05$). Handedness significantly differed between robotic and open approaches for raw time scores ($P < .0001$) and left-right ratio ($P = .03$) when controlling for the prior tasks completed, starting hand, prior robotic experience, and comfort level. These findings remain to be validated in larger cohorts.

Conclusion: The robotic technique reduces hand dominance in surgical trainees across all task domains. This finding contributes to the known advantages of robotic surgery.

Key Words: Robotics, Handedness, Hand dominance, Surgical education/training.

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INTRODUCTION

Handedness, or the innate dominance of one hand's dexterity over another, is generally not regarded as an impairment during open surgery, because the surgeon can adjust their body positioning to optimize intracorporeal maneuverability. Interestingly, although the choice of instrument can be changed according to hand preference, this accommodative capability does not exist in robotic surgery. Although this difference may initially seem to be a deficit, no such hindrance is routinely reported or perceived when using the robotic platform. It would then follow that the advantage of this system, namely the greater degree of freedom for rotational and/or fine motion, could obviate the surgeon's inherent hand dominance, thus eliminating another constraint encountered in a traditional surgical setting.

To examine this hypothesis, 10 residents who were relative novices at robotics were asked to complete various established skill sets with each hand, using both the open and the robotic technique. The relative performance of each hand for a given approach and task was then directly compared. In theory, if robotics eliminates the role of hand dominance, outcomes in this arm of the study would show similar hand performance distinct from open counterparts.

MATERIALS AND METHODS

Subjects and Design

Residents from the urology and obstetrics and gynecology residency programs at one tertiary care institution were recruited for voluntary participation in the study protocol. Those who self-reported as ambidextrous or left-hand dominant were excluded. Participants completed a questionnaire at enrollment pertaining to their level of training as well as their experience/comfort level using the robotic technique. Subjects were then asked to perform three tasks modified from the *Fundamentals of Laparoscopic Surgery* curriculum, namely (1) peg transfer, (2) precision cutting, and (3) intracorporeal suturing, as previously described.[1] The precision cutting involved excising a circle along a dotted line traced on paper, and the suture exercise focused on knot tying. Each of these tasks was first performed by hand and then using the da Vinci surgical system (Intuitive Surgical, Sunnyvale, California). Subjects were randomized to begin with the left or right hand and then asked to repeat the task with the opposite hand using both the open and robotic approaches for a given skill.

Evaluation

The primary end points used to assess the interchangeability of each hand first involved the raw time for exercise completion. Second, left:right (L:R) ratios were calculated by directly comparing the time score to complete a task with the left to the right hand: the greater the divergence of this number from 1, the larger the difference between hand performances.

Statistical Analysis

Linear mixed model analysis presented in analysis of variance format was used with raw time and L:R ratio data to assess the relative impact of handedness for the robotic and open techniques. The mixed model analysis controlled for independent variables reflecting hand use, task performed, and residency robotic training characteristics to determine whether the open versus the robotic approach afforded a significant differential in hand performance.

RESULTS

Ten subjects were enrolled, nine from the institutional urology program and one from the obstetrics/gynecology training program. Most were at a junior level of training (postgraduate years 1–3), reported nil to minimal robotics console experience, and described a mixed/low level of comfort using the robotic technique (**Table 1**).

Table 2 displays the technical tasks and skill sets the subjects completed using variable open and robotic approaches, comparing time with completion and L:R ratio, respectively. All of the tasks were completed faster using the open compared with the robotic approach for both hands. Knot-tying was the exercise in which the performance of the right and left hands was most disparate for open surgery (right 30.2 s, left 51 s), whereas the times to

Table 1.
Subject Baseline Characteristics

Subject No.	Starting Hand	PGY Level	Prior Robot Use?	Number of Cases at Console	How Comfortable?
1	R	1	N		Not
2	L	4	Y	2	Somewhat
3	R	1	Y	1	Not
4	L	7	Y	6	Somewhat
5	L	3	N		Not
6	R	2	N		
7	R	5	Y	1	Somewhat
8	R	3	N		
9	R	5	Y	2	Somewhat
10	L	3	N		

PGY, Postgraduate year.

Table 2.
Technical Tasks and Skill Sets Completed by Subjects (Peg Transfer, Circle Cutting, Knot Tying)

Peg Transfer	Open		Robotic	
	Right	Left	Right	Left
Time (s)	10.2	11.4	36.3	37.9
L:R ratio	1.14		1.17	
Circle Cutting	Open		Robotic	
	Right	Left	Right	Left
Time (s)	34	51.7	109.4	147.4
L:R ratio	1.58		1.36	
Knot Tying	Open		Robotic	
	Right	Left	Right	Left
Time (s)	30.2	51	60.2	58.6
L:R ratio	1.70		0.94	

complete this exercise with the robot were marginally longer, with less of a difference in mean times between both hands (right 60.2 s, left 58.6 s). Cumulatively, the difference in raw time score between both hands for all three tasks was significantly smaller using the robot, with the mean difference in performance scores being 12.5 seconds for the open and 8 seconds for the robotic modules ($P < .05$). Similarly, the overall L:R ratios were 1.45 versus 1.12 ($P < .05$), statistically favoring the robotic technique for dual-hand maneuverability.

The linear mixed model analysis presented as analysis of variance format for both raw time and the L:R ratio are displayed in **Table 3**. Subset A demonstrates that handedness remained significantly different between the robotic and open approaches in terms of raw time scores ($P < .0001$), even after controlling for task completed, starting hand, prior robotic experience, or comfort level. These results were corroborated with the L:R ratio analysis (**Table 3**) showing that the relative hand performance was different between the two techniques ($P = .03$) after controlling for similar variables.

DISCUSSION

The scope of robotics continues to exhibit expanding applications as it pertains to the field of urology as well as to all other surgical disciplines. This increasing use may be attributable to the known advantages conferred by this platform. These benefits are well described and involve

not only the technical aspects of refined optics, wristed-instrumentation, dexterity, and ergonomics, but also the diminished physical demands and constraints on the surgeon, who can operate from a seated position largely apart from the sterile field.[2,3] This pilot investigation adds to these known benefits by corroborating emerging data that handedness is not a limitation in robotic surgery. Of note, this lack of chirality may be particularly important in tasks that involve the interchange of hands, such as suturing and knot tying.

Prior work has examined the impact of robotics on dexterity and skill acquisition compared with pure laparoscopic techniques. Although there is a general dearth of literature on this topic, small studies have demonstrated that task achievement in terms of knot tying is significantly faster using robotics as opposed to the pure laparoscopic approach, irrespective of existing laparoscopic experience.[4] In a similar vein, Moorthy and colleagues performed an investigation with 10 surgeons having variable laparoscopic experience to examine relative hand dexterity during suturing tasks.[5] When an exercise was undertaken robotically, the subjects demonstrated a 40% relative reduction in the total time taken ($P = .01$) and had significantly reduced economy of motion for both hands ($P < .05$). Although these studies did not compare relative hand performance, they establish that robotics affords a level of

Table 3.
Linear Mixed Model in Analysis of Variance Format for Raw-Time Analysis and L:R Ratio Analysis

Raw Time Analysis

Independent Variables	Degrees of Freedom	F Value	P Value
Hand used	1	7.09	.01
Open versus robot	1	49.82	<.0001
Exercise/task	2	36.73	<.0001
Start hand	1	0.11	.77
Robotic experience	1	1.26	.38
Degree of comfort	1	0.03	.88

L:R Ratio Analysis

Independent Variables	Degrees of Freedom	F Value	P Value
Open versus robot	1	5.06	.03
Exercise/task	2	1.89	.17
Start hand	1	0.83	.46
Robotic experience	1	0.85	.45
Degree of comfort	1	0.15	.74

agility distinct from laparoscopy, and that this advantage is conferred to both hands of the operator.

The role of handedness in robotic and open systems has even been explored in a prior pilot investigation. Mucksavage et al evaluated manual dexterity measurements among 19 robotic novices who performed the Purdue Pegboard Test and needle-targeting exercises.[6] Although the performance scores for each hand were statistically disparate for the open approach, this difference was nullified for both tasks when they were done robotically. Although this work substantiates the conclusions laid forth herein, the design of the current investigation augments and furthers these findings. In fact, the present study examined outcomes in a greater number of simulated exercises and focused on endpoints apart from performance scores, such as time for task completion and the novel concept of L:R ratio that directly correlates the performance of each hand. Most importantly, this project controlled for known confounders to the univariate outcomes reported in the aforementioned investigation by the incorporation of a mixed model analysis. Therefore, this report cumulatively extrapolates and strengthens precedents that have been set by prior published work.

Despite the relative merits of these conclusions, several limitations and considerations warrant discussion for fu-

ture work on this subject. First, this pilot investigation needs validation in a larger group of subjects, including left-handed subjects and those with greater surgical experience, to make the results applicable beyond relatively novice, right-handed surgeons. To that point, follow-up studies should incorporate study arms evaluating residents as they perform the same set of skills using laparoscopic instruments and experienced surgeons completing tasks in the open, laparoscopic, and robotic settings. The data generated between these different study arms could provide clinically useful information about handedness and surgical learning curves between novice and experienced surgeons. Scheduling constraints with the residents enrolled in this study and the limited availability of the robot may have affected our analysis with regard to the number of repetitions of tasks completed per subject. To make future results more robust and to define a mechanism for the elimination of hand dominance by the surgical robot, follow-up studies could require subjects to not only repeat tasks multiple times but to also repeat tasks at different levels of motion scaling. Future studies should also record the number of errors each subject commits to detail the accuracy and precision of surgical task completion. Certainly, adding these components to the foundation set forth by this pilot study would enable future studies to further

describe the effects of hand dominance as they relate to different surgical modalities.

The impact of handedness also needs correlation with actual surgical outcomes. Indeed, one prior report looking at the impact of handedness on clinical outcomes showed that during robotic prostatectomy, a greater number of lymph nodes (right 3.26 vs left 2.76, P = .010) and a closer neurovascular bundle dissection (right 1.99 vs left 2.64 mm, $P < .001$) were routinely achieved on the right compared with the left.[7] As the authors comment, this finding may be attributable to the durable effect of surgeon handedness, in addition to the contribution of instrument laterality or assistant instrument positioning. Regardless, these are factors that can only be accounted for during in vivo surgery and cannot be capitulated in the training models typically used in these types of investigations. Despite these factors, however, the conclusions from this pilot study bring forth significant considerations for ensuing robotic training programs.

CONCLUSIONS

Handedness, or the innate dominance of one hand's dexterity over the other's, appears to be diminished in robotic surgery, in distinction to the clear impact of this factor on open surgical technique. This finding adds to the relative merits of the robotic approach, because it may have a significant role in the learning curve of tasks such as suturing and knot tying, which involve hand interchange.

Further investigation of this topic is warranted to focus on the import of this finding on intraoperative performance measures and clinical outcomes.

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