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Observations of Surgically Naïve Students During Robotic Simulation Drills Compared to Robotically Naïve Senior Surgeons

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Key Words

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ABSTRACT

Background: We compared robotic simulation performance between surgically naïve students with gaming experience and experienced surgeons without prior robotic training.

Methods: Twenty-three participants were analyzed: high school students (n = 6), medical students (n = 8), and experienced surgeons without robotic surgery experience (n = 9). Each participant completed three trials of six standardized robotic simulator drills using the Intuitive Surgical platform. Outcomes included overall simulator scores and the frequency of near-perfect scores (confidence builders, 90th–100th percentile) and low scores (frustration episodes, 0–10th percentile).

Results: Parametric analysis demonstrated no significant differences in overall simulator performance among the three cohorts across any drill, with mean overall scores of 52 for surgeons, 53 for high school students, and 60 for medical students ($p = 0.61$). All groups exhibited comparable learning curves, with an average improvement of 26% from the initial to final trial. In contrast, chi-square analysis revealed that surgically naïve students achieved significantly more confidence-building high scores and experienced significantly fewer frustration episodes than senior surgeons.

Conclusions: No statistically significant difference in mean early robotic simulation performance was detected between surgically naïve students and experienced surgeons without robotic experience. Students had more high-scoring and fewer low-scoring events in an exploratory event-level comparison. Differences in adaptation or frustration tolerance are possible explanations but were not directly tested. These findings support further investigation of early robotic simulation training across experience levels.

INTRODUCTION

The use of robotic platforms in surgery is increasing worldwide [1, 2]. The concept of robotic surgery was initially conceived as a means for a surgeon to remotely operate in resource-limited environments, such as military settings [3]. This vision has since evolved into contemporary robotic systems used in routine clinical practice. Early adoption of robotic technology occurred primarily among urologists and gynecologists, where the advantages of three-dimensional visualization and articulating instruments are particularly beneficial within the confined pelvic space [4]. Across specialties, younger surgeons have demonstrated higher rates of adoption compared with their senior counterparts [2].

To date, more than 12 million robotic procedures have been performed [5]. Utilization has increased from 1.8% of all surgical procedures in 2012 to over 15% in 2018 [5]. Barriers to widespread adoption include cost and reimbursement. A single robotic system costs over $2.5 million, and instruments are limited to 10–20 uses without the ability for refurbishment. In addition, consistent superiority over conventional minimally invasive approaches has not been clearly demonstrated. These factors raise questions regarding the drivers of rapid adoption, which may relate to improved surgeon ergonomics and a shorter learning curve [2, 7].

Formal training remains limited despite increasing utilization, with more than half of general surgery residents reporting no structured robotic training prior to their first robotic-assisted case [1, 6]. Graduating cardiothoracic surgery residents also report discomfort with robotic cardiac, pulmonary, and esophageal procedures, attributed to paucity of exposure in their training curriculum [7]. Earlier exposure to robotic platforms during medical school may facilitate skill acquisition during residency and improve baseline user comfort [9].

We aimed to evaluate performance on a robotic simulation platform among surgically naïve students and senior surgeons without prior robotic experience. Preliminary findings suggest that prior surgical expertise is not required for basic robotic skill acquisition [10]. We further sought to characterize limitations among senior surgeons that may contribute to delayed adoption of robotic surgery.

METHODS

Participants were stratified by level of medical and surgical training. Group 1 included six high school or premedical students with no medical experience. Group 2 included eight medical students without formal surgical training. These groups were collectively defined as "surgically naïve." Group 3 consisted of nine senior surgeons, defined as active laparoscopic, arthroscopic, or endoscopic surgeons with ≥20 years of experience and no prior robotic surgery training or exposure ("robotically naïve"). This cohort included surgeons from cardiothoracic surgery, neurosurgery, and orthopedic surgery. All students reported at least 5 years of video gaming experience, whereas none of the senior surgeons had significant experience with video or virtual reality gaming.

We hypothesized that the difference in performance between surgically naïve participants and senior surgeons would be less than 20%. A sample size of 10 participants per group was calculated to achieve 80% power. For nonparametric analyses, the two student groups were combined.

The da Vinci SimNow training platform (Intuitive Surgical), released in 2019, was used for simulation-based assessment on the Xi platform [6]. Six modules were selected such that all tasks could be completed in triplicate within a 90-minute session. Three modules were categorized as basic (Clutch, Wrist Articulation, and Energy Pedals 1), and three as advanced (Sea Spikes 1, Ring Rollercoaster, and

Three Arm Relay 1). The structured progression from basic to advanced tasks allowed participants to familiarize themselves with robotic controls before attempting more complex maneuvers and enabled stratification of technical performance across skill levels.

Performance was evaluated using box-and-whisker plots to summarize score distributions, including minimum, maximum, median, and interquartile ranges (Figure 1). A grand mean score was calculated (average of scores for all six drills) for each group to assess overall performance. Scores in the 90th–100th percentile were operationally defined as "near-perfect performance" or "confidence builders," whereas scores in the 0–10th percentile were operationally defined as "frustration episodes." The latter designation refers strictly to low simulator scores, not a validated psychological measure of frustration. These categorical outcomes were compared between student and surgeon groups using chi-square analysis of a 2×2 contingency table; repeated attempts from participants contributed multiple observations.

RESULTS

The final analysis included 23 participants: six high school students and eight medical students classified as "surgically naïve," and nine experienced surgeons classified as "robotically naïve." Studies were conducted in 2022, with all surgeons recruited from our institution.

Mean performance scores were similar across groups. High school students had a mean score of 52.7, medical students 60.3, and experienced surgeons 51.7, with no statistically significant differences observed.

Box-and-whisker plots (**Figure 1**) and drill-specific line graphs were used to evaluate performance trends across repeated attempts. Medical students achieved the highest mean score on the

third attempt in 5 of 6 drills and demonstrated the greatest improvement across attempts, with an average slope of 13.9 compared with smaller gains among experienced surgeons and high school students. Representative trends for the Clutch and Three Arm Relay drills are shown in **Figures 2** and **3**. These differences did not reach statistical significance.

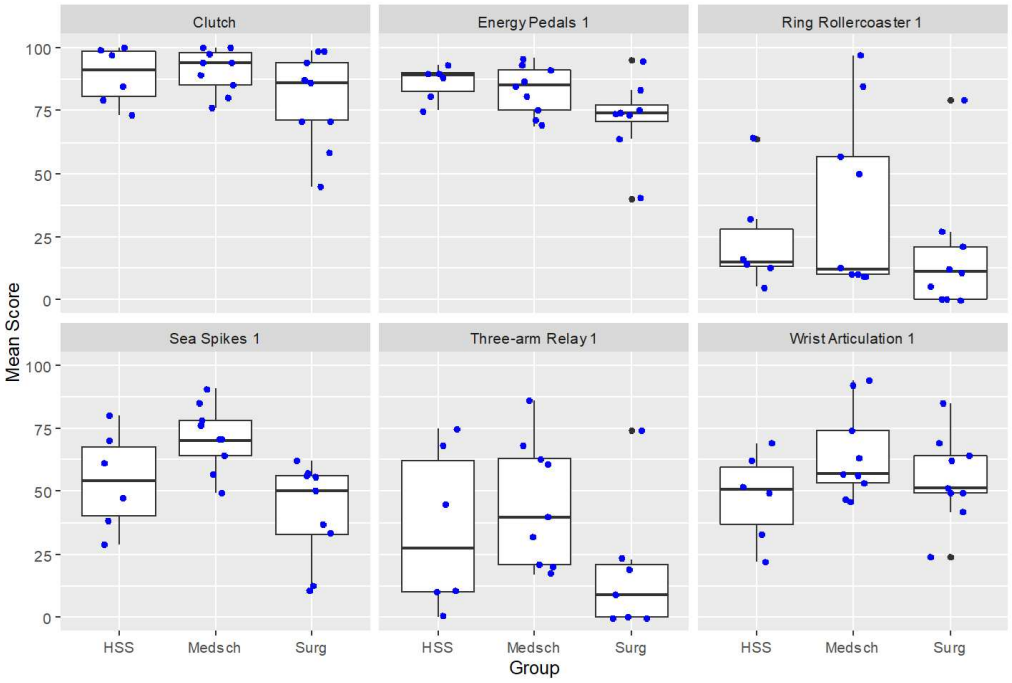

Figure 1. Box-and-whisker plots of scores across six robotic simulation drills by participant group (all between-group p > 0.05).

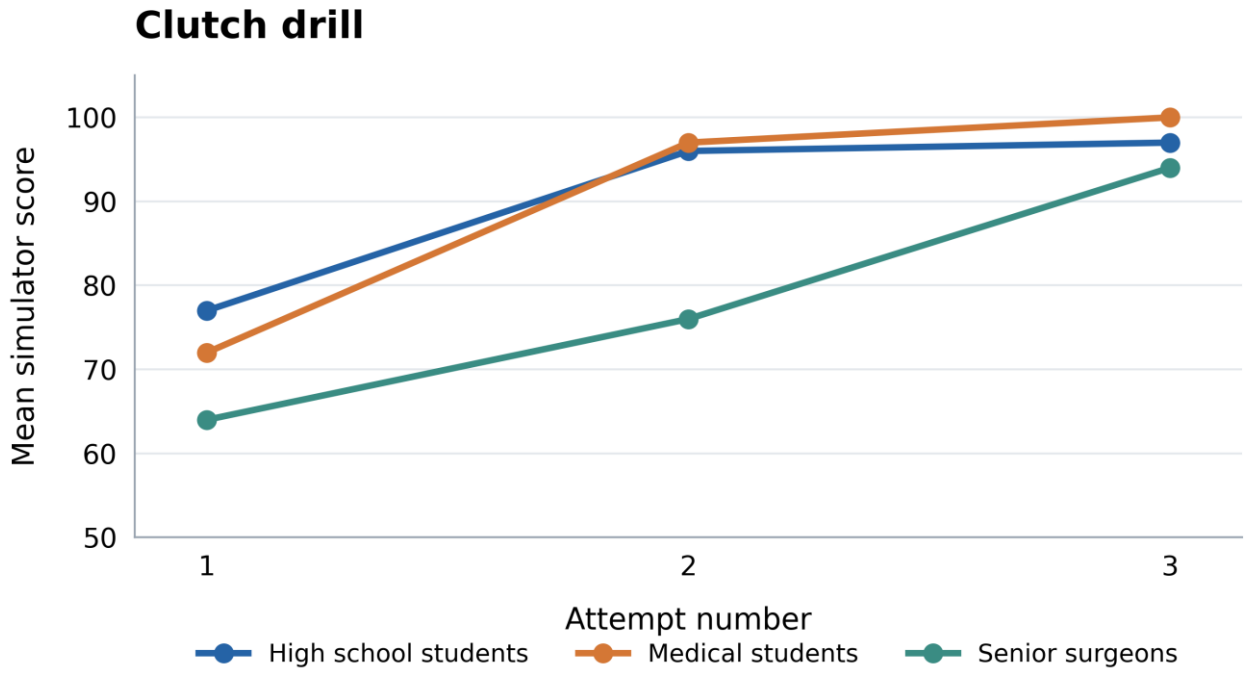

Figure 2. Mean simulator score across three attempts on the Clutch drill. The y-axis is truncated to emphasize differences in scores.

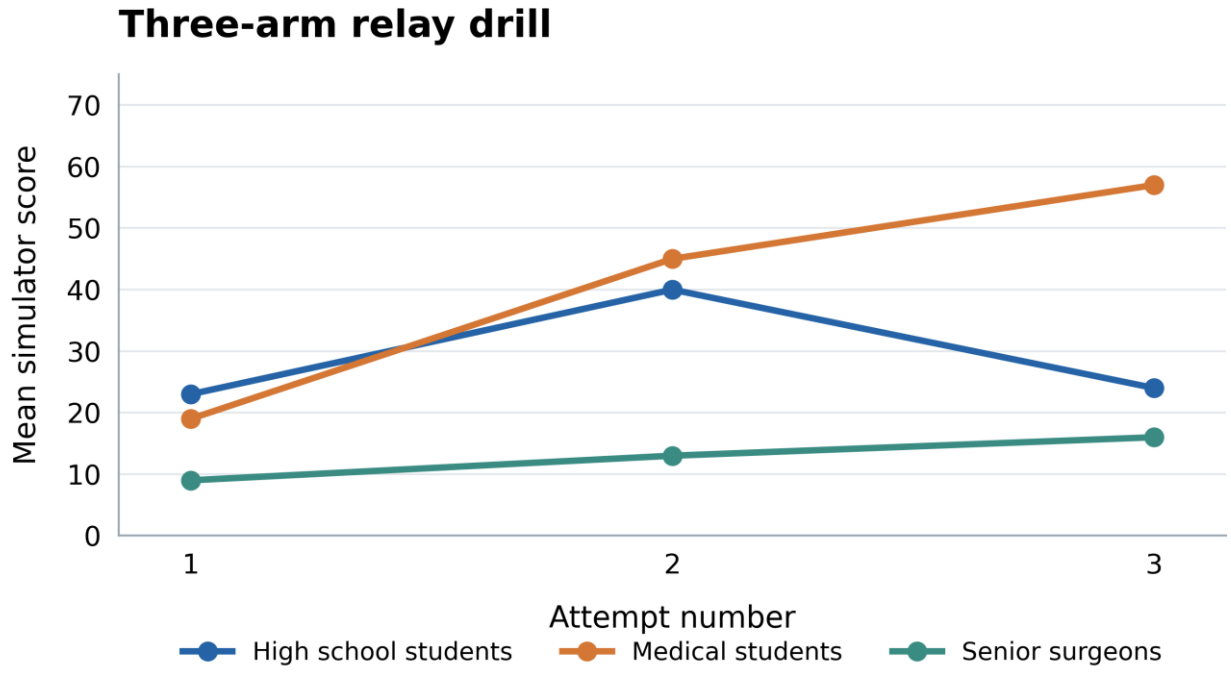

Figure 3. Mean simulator score across three attempts on the Three-arm Relay drill

An exploratory event-level chi-square comparison found that surgically naïve students had more near-perfect scores (90th–100th percentile; confidence builders) and fewer low scores (0–10th percentile; frustration episodes) than experienced surgeons (Pearson $\chi^2 = 22.36$, $p < 0.0001$; Table 1). Because repeated attempts within participants were not independent, this p value is descriptive and should not be interpreted as participant-level statistical evidence.

Table 1. Distribution of extreme simulator performance events among students and surgeons.

	Frustration episodes[1]	Confidence builders[2]	**Marginal Row Totals**
Students (n = 14)	27 (26.5%)	75 (73.5%)	102
Surgeons (n = 9)	48 (61.5%)	30 (38.5%)	78
Marginal Column Totals	75	105	180

Frustration episodes: scores in the 0th–10th percentile; confidence builders: scores in the 90th–100th percentile. Percentages are within-group proportions of extreme-score events, not of all trials. Exploratory event-level Pearson $\chi^2 = 22.36$, $p < 0.0001$

DISCUSSION

Surgically naïve students demonstrated a trend toward higher mean performance scores compared with robotically naïve surgeons, although this did not reach statistical significance. These findings support our hypothesis that baseline surgical experience does not confer a significant advantage during early robotic simulation training.

Observations during task performance provide additional insight into these results. Students appeared more willing to engage with the platform, persist through errors, and iteratively improve performance. In contrast, surgeons more frequently expressed frustration during early attempts, at times attributing errors to the system before recognizing operator factors. Notably, once familiar with the

interface, surgeons demonstrated improved control and efficiency, suggesting that initial adaptation represents a key barrier in the robotic learning curve.

Surgically naïve participants had more near-perfect scores and fewer low simulator scores than experienced surgeons in the exploratory event-level comparison. One theoretical explanation is that early success and differences in tolerance of unfamiliar interfaces may affect engagement with robotic training. However, frustration tolerance was not formally measured, and "frustration episodes" refers only to low simulator scores rather than psychological distress. Thus, any relationship between frustration, learning, and adoption of robotic surgery remains hypothetical. Differences in gaming experience and prior exposure to technology may also contribute.

Importantly, our findings suggest that the skills required for robotic surgery are not inherently dependent on prior operative experience. This is consistent with prior studies demonstrating limited correlation between laparoscopic experience and early robotic performance [4, 11, 12]. These observations raise questions regarding the determinants of proficiency in robotic training, which likely include factors beyond surgical experience alone. Prior work suggests that performance in simulation may be influenced by extracurricular skill sets. Harper et al. demonstrated improved robotic performance among individuals with athletic or musical training, whereas gaming experience was not predictive [8]. In contrast, Hvolbek et al. reported a potential advantage among participants with prior gaming experience [13]. Collectively, these findings suggest that robotic skill acquisition is multifactorial, necessitating elements of hand–eye coordination, spatial awareness, and adaptive learning.

Study limitations include the small sample size and use of simulation-based tasks that may not reflect operative performance. All students had substantial prior gaming experience, whereas senior surgeons did not; therefore, effects of gaming familiarity cannot be separated from training level or

surgical experience. The repeated simulator attempts within participants also limit interpretation of event-level chi-square comparisons, because these observations are not fully independent. Furthermore, the term “frustration episodes” denotes low simulator scores rather than a validated measure of subjective frustration. The lack of long-term outcome assessment further limits generalizability. The simulation tasks are simplified and may not reflect operative skills such as suturing, dissection, or stapling.

Although our study was not designed to evaluate specific operative skills, the observed variability within both student and surgeon cohorts supports the need for individualized approaches to robotic training. Future investigations should incorporate detailed assessment of prior experiences, including athletics, musical training, and simulation exposure, to better characterize predictors of performance and optimize training paradigms.

Despite ongoing debate regarding cost and clinical benefit, adoption of robotic surgery among trainees and early-career surgeons continues to expand. In contrast, the rate of uptake among senior surgeons remains slower, likely reflecting both familiarity with established techniques and barriers associated with the learning curve. This generational divide underscores the importance of implementing structured training pathways and mentorship programs to encourage adoption and ensure effective integration of robotic platforms into contemporary surgical practice.

CONCLUSION

No statistically significant difference in mean early robotic simulator performance was detected between surgically naïve students and robotically naïve senior surgeons in this small cohort; this finding does not establish equivalence. Students demonstrated more high-scoring and fewer low-scoring events in an exploratory comparison that did not account for clustering of repeated trials within participants. Differences in adaptation or frustration tolerance are theoretical explanations that require direct

assessment. These observations support further study of individualized robotic simulation training across levels of surgical experience.

TABLE & FIGURE LEGENDS

Table 1. Distribution of extreme simulator performance events among students and surgeons.

Figure 1. Box-and-whisker plots of performance scores for the six robotic simulation drills across study groups. No statistically significant between-group differences were detected (all $p > 0.05$).

Figure 2: Graph of each group's mean per attempt on the clutch drill. The axes have been adjusted as no group had a mean score below 50 on the first attempt. This was the first drill participants completed.

Figure 3: Graph of each group's mean score on the Three-arm Relay Drill. This was the last drill participants completed and would be considered the hardest drill.

STATEMENTS AND DECLARATIONS

Ethics approval: The study was determined to be exempt from institutional review board review.

Consent to participate: Informed consent was obtained from all participants.

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Data availability: The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable institutional and ethical restrictions.

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