

Effectiveness of an Eight-Week Simulation-Based Laparoscopic Training Program for Coloproctology Residents: A Prospective Pretest–Posttest Study

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Abstract

Background

Laparoscopic surgery provides important patient benefits, including faster recovery, shorter hospital stays, and reduced inflammatory response. However, laparoscopic skill acquisition requires the development of complex psychomotor abilities through deliberate practice. Although simulation-based training and the Fundamentals of Laparoscopic Surgery (FLS) program are widely used in surgical education, evidence regarding structured FLS-based training in coloproctology residency programs, particularly in Latin America, remains limited. This study evaluated the effectiveness of an eight-week FLS-based simulator training program in improving laparoscopic skills among coloproctology residents in Mexico.

Methods

A prospective pretest-posttest study was conducted at the Coloproctology Service of the Antiguo Hospital Civil “Fray Antonio Alcalde”, Guadalajara, Mexico. Fourteen coloproctology residents participated in an eight-week simulator-based training program. Technical skills were assessed before and after the intervention using the five standardized FLS tasks: peg transfer, precision cutting, ligating loop, intracorporeal suturing, and extracorporeal suturing. Competency was determined according to established FLS performance criteria. Participants were additionally categorized according to prior laparoscopic experience and video game use. Descriptive and comparative statistical analyses were performed using SPSS version 25, with statistical significance established at $p < 0.05$.

Results

All 14 residents completed the training program and were included in the final analysis. Following the intervention, participants demonstrated significant improvements in laparoscopic technical performance across all evaluated FLS tasks. Significant gains were observed in every task assessed, reflected by reductions in task completion times and improvements in accuracy scores. Residents with previous laparoscopic experience demonstrated higher baseline technical performance than those without prior experience. In contrast, no significant differences in laparoscopic performance were observed according to the frequency of video game use.

Conclusions

An eight-week structured FLS-based simulation training program was associated with significant improvements in laparoscopic technical skills among coloproctology residents. These findings support the incorporation of standardized simulation-based curricula into coloproctology training programs and

provide evidence for the feasibility and educational value of FLS-based training in Latin American residency settings.

Trial registration:

The study protocol was approved by the Institutional Research Ethics Committee (CEI 262/24). The study was not registered in any database.

Background

Laparoscopic surgery has demonstrated several advantages and benefits for patients [1]. In coloproctology, laparoscopic colorectal surgery has been associated with earlier recovery of bowel function, shorter hospital stays [2], and reduced inflammatory response [3]. Among its applications, colorectal cancer [4, 5] and inflammatory bowel disease [6–8] are the most common indications. However, compared with open surgery, laparoscopy is considered more difficult to learn [9]. Laparoscopic colorectal procedures may also be technically demanding due to complex pelvic anatomy and limited surgical workspace. Its success largely depends on the surgeon's ability to develop and refine non-intuitive psychomotor skills [10–12], which can only be acquired through experience and repeated practice [10]. Therefore, continuous and deliberate practice is required to achieve surgical competence [13].

Training exclusively in the operating room presents several challenges, as it may increase operative time and expose patients to procedures performed by residents who may not yet have sufficient experience [13]. Consequently, surgical trainees must develop fundamental skills outside the operating room before performing procedures on patients [11, 12].

Currently, no universally adopted model exists for the acquisition of laparoscopic skills. Traditionally, these skills have been taught through intensive hands-on courses [14]. In recent years, simulation has increasingly been incorporated into surgical education to enhance technical training [15]. A variety of laparoscopic simulators are now available, ranging from box trainers to virtual reality platforms [16]. To promote standardized surgical training, the American College of Surgeons (ACS) and the Association of Program Directors in Surgery (APDS) developed a national skills curriculum that includes modules for open, laparoscopic, and endoscopic surgery [17]. The Fundamentals of Laparoscopic Surgery (FLS) program, developed by the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) and endorsed by the ACS, is an internationally recognized educational program designed to teach and assess essential laparoscopic technical skills [18]. FLS certification is currently required by several regulatory and certification bodies worldwide [19].

Based on these recommendations, many residency programs worldwide have implemented structured laparoscopic curricula using a stepwise approach, in which junior residents acquire basic skills such as

camera navigation and hand–eye coordination, while senior residents focus on more advanced techniques, including laparoscopic suturing [17].

Previous studies have shown that structured laparoscopic training programs combining theoretical instruction with practice using synthetic models, virtual simulators, and animal models significantly improve residents' performance, resulting in higher theoretical scores, greater technical proficiency, and shorter task completion times [20, 21]. Furthermore, early assessment through programs such as FLS may help evaluate technical and cognitive skills before residents are exposed to more complex laparoscopic procedures [22].

Although simulation-based training has been widely incorporated into surgical education, evidence regarding structured FLS-based curricula in coloproctology residency training remains limited, particularly in Latin American institutions. Therefore, this study aimed to evaluate the outcomes of an eight-week simulation-based training program using FLS tasks in coloproctology residents at the *Antiguo Hospital Civil "Fray Antonio Alcalde"* in Guadalajara, Jalisco, Mexico.

Methods

Study design

This was a prospective single-group pretest-posttest study conducted among coloproctology residents participating in an eight-week simulator-based training program.

Setting and participants

The study was conducted at the Coloproctology Service of the *Antiguo Hospital Civil "Fray Antonio Alcalde"*, Guadalajara, Mexico. The study population consisted of residents enrolled in the Coloproctology residency program who participated in an eight-week simulator-based training program.

Unit of analysis and study variables

The main exposure was completion of an eight-week simulator-based laparoscopic training program. The dependent variable was improvement in technical skills for performing laparoscopic procedures, assessed using the FLS tasks.

Sample size and sampling

A convenience sample was used. Participants were recruited through non-probabilistic consecutive inclusion.

Selection criteria

First- and second-year coloproctology residents participating in the eight-week training program were included. Residents from other medical specialties or who did not sign the informed consent form were excluded from the study. Further, residents who did not complete the training program or who chose to withdraw from the study were eliminated.

Training program and skills assessment

The present study was conducted at the Coloproctology Service of the Antiguo Hospital Civil Fray Antonio Alcalde, Guadalajara, Mexico. An eight-week training course was implemented for 14 coloproctology residents (seven first-year and seven second-year residents).

Before the start of the training program and again at the end of the eight-week intervention, residents' technical skills were evaluated using the FLS tasks, which assess five standardized exercises: peg transfer, precision cutting, ligating loop, and intracorporeal and extracorporeal suturing. Task competency was assessed according to predefined criteria, as described in Table 1. Competency was defined according to task-specific benchmarks, including completion time and accuracy parameters. Assessments were conducted by a board-certified surgeon with extensive experience in advanced laparoscopic and robotic surgery, using a structured questionnaire adapted from the FLS Skills Training Scoresheet from the Technical Skills Proficiency-Based Training Curriculum [23].

The original instrument was translated into Spanish by the research team and modified to collect additional information relevant to this study, including previous laparoscopic experience and video game use. Prior laparoscopic practice was defined as self-reported participation in laparoscopic procedures in the operating room at least three times per week. Participants were also categorized according to video game use as follows: more than three times per week, less than three times per week, or no video game use. These data were self-reported. The Spanish-language adapted data collection form used in this study, and its translation to English is provided as Supplementary Material 1.

Table 1
Criteria to evaluate task competency

Task	Competency
Peg Transfer	Completed within 48 seconds without dropping objects outside the field of view.
Precision cutting	Completed within 1 minute 38 seconds.
Ligating loop	Completed within 53 seconds, with the loop securely placed around the appendix and positioned within 1 mm of the marked line.
Extracorporeal suturing	Completed within 2 minutes 16 seconds. The suture passed through the Penrose drain within 1 mm of the marked points, the slit was fully closed, and the knot was secure (no slippage or air knots).
Intracorporeal suturing	Completed within 1 minute 52 seconds. The suture passed through the Penrose drain within 1 mm of the marked points, the slit was fully closed, and the knot was secure (no slippage or air knots).

Data collection and management

Observed data were collected and recorded in an electronic statistical database using spreadsheets specifically designed for this research project. The data obtained from each observation unit was entered into the corresponding data collection instruments developed by the principal investigator. Data was entered into a password-protected electronic database by the principal investigator and checked for completeness prior to analysis to minimize potential sources of bias.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences Statistics Software (SPSS), version 25 (IBM Corp., Armonk, NY, USA). For descriptive analysis, nominal categorical variables were expressed as frequencies and percentages. Continuous variables with parametric distribution were expressed as means $\pm$ standard deviation (SD), whereas non-parametric variables were expressed as medians with 5th–95th percentiles.

For comparisons between two groups, the Student's *t*-test was used for parametric quantitative variables, while the Mann–Whitney *U* test was used for non-parametric quantitative variables. Categorical variables were compared using Fisher's exact test. A *p* value < 0.05 was considered statistically significant.

Ethical considerations

All procedures in this research were conducted in strict accordance with the *Regulations of the General Health Law on Health Research* of Mexico (latest reform published in the *Diario Oficial de la Federación* on April 2, 2014; Title II, Chapter I). According to Article 17, Section I, this study was classified as research without risk. In accordance with Article 13, the dignity, rights, and well-being of all participants were

always respected. Participants were informed that the results of the study would be available to them upon request.

Ethics approval or consent to participate

The study protocol was approved by the Institutional Research Ethics Committee of the *Antiguo Hospital Civil "Fray Antonio Alcalde"*, Guadalajara, Mexico (approval number: CEI 262/24). All participants provided written informed consent prior to participation in the study.

Results

A total of 14 first- and second-year coloproctology residents who participated in the eight-week training program aimed at improving laparoscopic technical skills were evaluated. The participants had a mean age of 31.5 years, and the majority were male (64%). Seventy-one percent of residents reported prior laparoscopic practice, defined as participation in the operating room at least three times per week, with at least one laparoscopic procedure performed per day during those sessions. Additionally, 57% reported playing video games, of whom 43% did so more than three times per week (Table 2).

Table 2
Characteristics of the coloproctology residents who participated in this study

Characteristic	n = 14
	Medium (SD)
Age	31.5 ± 1.8
	% (n)
Sex	
<i>Female</i>	36 (5)
<i>Male</i>	64 (9)
Previous practice	
Yes	71(10)
No	29 (4)
Plays videogames	
Yes	57 (8)
No	43 (6)
Plays videogames > 3 times per week	
Yes	43 (6)
No	57 (8)

To assess technical skills for laparoscopic surgery after the eight-week FLS-based training program, performance in terms of time during the peg transfer task was compared before and after training. As shown in Table 3, task completion time decreased significantly after training ($p < 0.001$), as did the number of dropped objects ($p < 0.001$). Similarly, the time required to complete the precision cutting task decreased ($p < 0.001$), and 100% of participants were able to cut within the marked line after training ($p < 0.001$). For the ligating loop task, completion time also decreased significantly ($p < 0.001$) after the intervention, along with the distance from the marked line ($p < 0.001$). No differences were observed in the percentage of participants who performed a secure loop before and after training.

Table 3

Technical skills (peg transfer, precision cutting and ligating loop) before and after training

Task	Before training	After training	p Values
	n = 14	n = 14	
Peg Transfer			
Time (sec) ^a	336 ± 54	146 ± 26	< 0.001
Dropped objects ^b	1 (0–3)	0 (0–1)	< 0.001
Precision cutting			
Time (sec) ^b	299 (156–625)	187.5 (104–320)	0.001
Cut within the marked line ^c	0 (0)	100 (14)	< 0.001
Ligating loop			
Time (sec) ^b	95 (60–210)	49 (29–134)	< 0.001
Secure loop ^c	86 (12)	100 (14)	0.14
Distance from the marked line (mm) ^b	1 (0–2)	0 (0–0)	< 0.001
^a Media ± SD, Student's T test; ^b Media (percentiles), Mann U Whitney; ^c % (n). Chi ² test			

Performance in extracorporeal and intracorporeal suturing tasks was subsequently evaluated (Table 4). The time required to complete the extracorporeal suturing was significantly reduced after training ($p < 0.001$). The percentage of participants who performed a secure knot increased from 28% to 93% after training. The percentage of participants achieving a closed loop also increased from 57% to 100%, while the marking distance and the percentage of drain slippage decreased, although not significantly ($p = 0.005$ and 0.006 , respectively).

Regarding the intracorporeal suturing, completion time was also significantly reduced after training ($p < 0.001$). The percentage of participants achieving a secure knot and a closed loop increased from 57% to 93% and from 57% to 100%, respectively. The marking distance decreased during this task ($p < 0.001$); however, no significant differences were observed in the percentage of drain slippage before and after training ($p = 0.06$).

A sub-analysis was performed to compare performance in terms of time during the peg transfer, precision cutting, ligating loop, extracorporeal suturing, and intracorporeal suturing tasks between participants with and without a history of video game use. No significant differences in task completion time were observed at baseline or after training based on video game experience (data not shown).

Table 4
Technical skills (extracorporeal suturing and intracorporeal suturing) before and after training

Task	Before training	After training	p Values
	n = 14	n = 14	
Extracorporeal suturing			
Time (sec) ^a	312 ± 109	172 ± 76	< 0.001
Secure knot ^c	28 (4)	93 (13)	< 0.001
Closed loop ^c	57 (8)	100 (14)	0.006
Marking distance (mm) ^b	1 (0–3)	0 (0–1)	< 0.001
Drain slippage ^c	57 (8)	7 (1)	0.005
Intracorporeal suturing			
Time (sec) ^a	299 ± 76	183 ± 93	< 0.001
Secure knot ^c	57 (8)	93 (13)	0.02
Closed loop ^c	57 (8)	100 (14)	0.006
Marking distance (mm) ^b	1 (0–2)	0 (0–1)	< 0.001
Drain slippage ^c	36 (5)	7 (1)	0.06
aMedia ± SD, Student's T test; bMedia (percentiles), Mann U Whitney; c% (n). Chi ² test			

Finally, performance was compared between participants with and without prior laparoscopic practice. One hundred percent of residents with prior practice achieved cutting within the marked line and a secure loop in the precision cutting and ligating loop tasks, respectively. In the extracorporeal suturing task, 93% of participants with prior practice performed a secure knot compared with 29% of those without prior experience. Additionally, 100% of residents with prior practice achieved a closed loop, and only 7% presented drain slippage, with significant differences compared to residents without prior practice (Table 5). Participants with prior laparoscopic practice also demonstrated better performance in terms of task completion time across the peg transfer, precision cutting, ligating loop, and both intra- and extracorporeal suturing. They also had fewer dropped objects during the peg transfer task and shorter distances from the marked line in the ligating loop and suturing tasks (Table 5).

Table 5
Comparison of task performance in residents with and without prior practice

Task	Previous practice	w/o previous practice	p Values
Precision cutting			
Cut within the marked line ^a	100%	0%	< 0.001
Time (sec) ^b	192 ± 61	320 ± 137	< 0.001
Ligating loop			
Secure knot ^a	100%	86%	0.24
Time (sec) ^b	53 ± 26	106 ± 46	< 0.001
Distance from the marked line (mm) ^b	0.0 ± 0	0.86 ± 0.77	0.001
Extracorporeal knot-tying			
Secure knot ^a	93%	29%	0.001
Closed loop ^a	100%	57%	0.008
Drain slippage ^a	7%	57%	0.006
Time (sec) ^b	172 ± 76	312 ± 109	< 0.001
Distance from the marked line (mm) ^b	0.07 ± 0.2	1.07 ± 0.8	< 0.001
Intracorporeal knot-tying			
Secure knot ^a	93%	57%	0.03
Closed loop ^a	100%	57%	0.008
Drain slippage ^a	7%	36%	0.08
Time (sec) ^b	183 ± 92	299 ± 75	< 0.001
Distance from the marked line (mm) ^b	0.07 ± 0.2	0.93 ± 0.7	< 0.001
Peg transfer			
Time (sec) ^b	146.3 ± 26	336 ± 53	< 0.001
Dropped objects ^b	0.21 ± 0.4	1.2 ± 0.8	< 0.001
^a n(%), Chi ² test; ^b Media ± SD; Student's T test			

Discussion

The present study demonstrated a significant improvement in laparoscopic technical skills among coloproctology residents after completing an eight-week simulation-based training program based on the Fundamentals of Laparoscopic Surgery. This internationally recognized program aims to provide standardized fundamental knowledge in laparoscopic surgery and to teach a set of technical skills exercises that enhance clinical performance during laparoscopic procedures [18].

When comparing performance in the peg transfer, precision cutting, and ligating loop tasks before and after training, it was observed that a significant improvement in efficiency and precision was observed across these tasks, including reduced errors and consistent achievement of task objectives. These findings confirm previous reports indicating that training related to laparoscopic surgical skills enhances skill acquisition in novice surgeons and may facilitate the transfer of these competencies to the operating room [17]. This improvement may be explained by the principles of deliberate practice, where repetitive, structured training in a controlled environment enhances the acquisition of psychomotor skills.

Similarly, when comparing performance in the extracorporeal and intracorporeal suturing tasks before and after training, performance improvements were also observed in both suturing tasks, reflected by increased knot security, improved loop closure, and enhanced precision. These findings further support the role of simulation-based training as an effective strategy for the safe acquisition of fundamental laparoscopic skills. From an educational perspective, these findings support the integration of structured simulation-based training early in residency programs to enhance skill acquisition and potentially improve patient safety.

Laparoscopic surgery and video gaming are activities that require visuomotor and visuospatial skills; therefore, it has been suggested that previous experience with video games may improve performance in laparoscopic skills. However, studies have not yet conclusively demonstrated this relationship [24]. In the present study, no differences in task performance were observed at the beginning or at the end of the training between residents with and without previous video game experience.

Previous studies have reported that residents who perform more laparoscopic surgery early in their residency benefit from earlier evaluation of basic laparoscopic skills [16]. In this study, participants who had previous laparoscopic practice three times per week demonstrated consistently better performance across all evaluated tasks, indicating a positive association between prior laparoscopic exposure and technical skill acquisition. These findings support the use of FLS as an early and objective tool for assessing laparoscopic knowledge and technical competence of laparoscopic knowledge and skills and should be performed before a significant increase in complex laparoscopic surgery during training. It has also been previously described that medical students with laparoscopic skills achieve better results in laparoscopic skills tests than students without previous practice, suggesting that skill transfer occurs. Furthermore, current studies report that the acquisition of laparoscopic skills is essential in surgical training programs [25].

This study had some limitations. First, the study population was limited to residents from the coloproctology service, which may not be representative of the broader community of residents from other surgical specialties. In addition, further research is needed to explore the association between the skills acquired during training and long-term technical outcomes during residency. Despite these limitations, this study provides evidence of the effectiveness of FLS-based training in improving laparoscopic technical performance among coloproctology residents. As a future perspective, it is proposed to extend this study to other surgical specialties and to conduct follow-up studies to evaluate the relationship between the skills acquired during training and performance during residency.

Conclusions

An eight-week FLS-based simulation training program significantly improved laparoscopic technical skills in coloproctology residents. Prior laparoscopic experience, but not video game use, was associated with better performance, supporting the role of structured surgical exposure in skill acquisition.

Abbreviations

ACS

American College of Surgeons

APDS

Association of Program Directors in Surgery

FLS

Fundamentals of Laparoscopic Surgery

SAGES

Society of American Gastrointestinal and Endoscopic Surgeons

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Institutional Research Ethics Committee of the Antiguo Hospital Civil “Fray Antonio Alcalde”, Guadalajara, Mexico (approval number: CEI 262/24). All participants provided written informed consent prior to participation in the study.

Consent for publication

Not applicable

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Author Contribution

CGG and FVC: conceived and designed the study AGC conceived and designed the study, collected and analyzed the data, interpreted the results and drafted the manuscript. CGG, FVC, AGD, JGD, MSN interpreted the results and drafted the manuscript. RCN critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript

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Not applicable

Data Availability

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

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