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Article

Role of Endotrainers in Laparoscopic Surgical Training of Young Surgeons

Assam Arshid[1], Huda Jabbar[2], Shafaq Nisar[2], Khadija Shafiq[2], Mommna Komal Arshid[2], Bilal Masood[3]

[1] General Surgery Department, Lahore General Hospital, Lahore, Pakistan
[2] Lahore General Hospital, Lahore, Pakistan
[3] Department of Community Medicine, Bolan Medical College, Quetta, Pakistan

Correspondence:
assamarshid786@gmail.com

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ABSTRACT

Background: Laparoscopic surgery is the preferred technique for many surgical procedures due to its minimal invasiveness and faster recovery, but effective training remains a challenge, especially in low-resource settings lacking formal simulation tools. There is a significant need to evaluate cost-effective alternatives, such as homemade endotrainers, to bridge the skill acquisition gap among surgical trainees. **Objective**: To assess the effectiveness of low-cost endotrainers in improving the laparoscopic skills—specifically peg transfer, ligating endoloop, intracorporeal knotting, and extracorporeal knotting—among postgraduate general surgical trainees over a one-month training period. **Methods**: This was a prospective observational study conducted at Lahore General Hospital with a sample of 30 third- and fourth-year general surgery residents. Inclusion criteria were residency status and willingness to participate; exclusion criteria included prior advanced laparoscopic training. Performance was assessed pre- and post-training using timed skill tasks and failure rates, evaluated by blinded laparoscopic surgeons. Ethical approval was granted by the Institutional Review Board, with all procedures adhering to the Helsinki Declaration. Data were analyzed using SPSS v27, employing paired sample t-tests and McNemar's test to assess improvements. **Results**: Statistically significant improvements were observed in mean task times: peg transfer (10.87 to 2.57 min, p=0.012), endoloop (12.75 to 7.50 min, p=0.015), intracorporeal knotting (7.13 to 2.10 min, p=0.049), and extracorporeal knotting (11.67 to 3.33 min, p=0.015). Task failure rates also declined notably. Clinically, trainees demonstrated enhanced coordination, efficiency, and safety. **Conclusion**: Cost-effective, homemade endotrainers significantly improve basic laparoscopic skills among surgical residents, supporting their integration into surgical training, especially in resource-limited environments to enhance procedural safety and patient outcomes.

Keywords: Laparoscopy Training, Endotrainers, Simulation-Based Learning, Surgical Education, Motor Skill Acquisition, Low-Cost Simulation, Surgical Residency Training

INTRODUCTION

Laparoscopic surgery has increasingly become the gold standard for a wide range of basic and advanced surgical procedures due to its advantages such as reduced postoperative pain, faster recovery times, and improved cosmetic outcomes. However, despite its growing adoption, acquiring laparoscopic skills remains a significant challenge, particularly in low- and middle-income countries where resources are limited. A major barrier in these settings is the lack of formal skill labs, costly simulation systems, and access to structured training environments (1,2). Traditional surgical training often involves learning directly in the operating room, which presents ethical concerns, patient safety risks, and variability in exposure. This underscores the need for alternative, accessible methods of skill acquisition that can provide consistent and repeatable practice environments for young surgeons.

Simulated laparoscopic training using endotrainers offers a promising solution to address these challenges. These devices, especially when homemade and cost-effective, allow trainees to practice core skills such as hand-eye coordination, depth perception, and instrument manipulation outside of high-pressure clinical settings. Research has consistently supported the use of simulation models, including endotrainers and virtual reality tools, for accelerating the learning curve in laparoscopic surgery and improving outcomes (3,4). The role of endotrainers is particularly vital in early residency, where exposure to laparoscopic procedures may be sporadic and insufficient to

build competence through operative experience alone. Studies have shown that even simple tasks like peg transfer, ligation with endoloops, and knot tying—both intracorporeal and extracorporeal—can significantly improve with dedicated endotrainer practice (5,6).

Furthermore, structured simulation programs have demonstrated that training outside the operating theater leads to measurable improvements in technical proficiency and procedural efficiency (7). As the surgical landscape evolves with the incorporation of robotic and telerobotic systems, the need for structured, competency-based, and stepwise simulation training becomes more pronounced (5). In developing countries, where high-fidelity simulators and robotic systems are often not feasible, low-cost alternatives such as wooden box endotrainers equipped with basic cameras have proven effective in skill development, serving as vital stepping stones in the training continuum (2).

The current generation of surgical residents often begins learning laparoendoscopic techniques alongside or even before mastering open surgical procedures. This represents a shift from the traditional apprenticeship model and demands an educational paradigm that supports early and repeated simulation exposure (14,15). Literature has highlighted that simulation-based learning not only improves technical outcomes but also enhances non-technical skills such as decision-making, spatial awareness, and procedural planning (17,18). Moreover, simulation training has been associated with reduced complication rates, particularly in complex procedures like laparoscopic bariatric surgery, where formal training has been shown to significantly decrease both postoperative complications and mortality (16).

Given these advantages, the implementation of endotrainer-based training modules for surgical residents is not just a supplemental educational tool but a necessity in modern surgical education, especially in resource-constrained environments. This study aimed to evaluate the role of endotrainers in improving laparoscopic skills among postgraduate surgical trainees using a cost-effective, homemade simulation model. The research question guiding this study was: Does training with an inexpensive endotrainer significantly enhance the technical performance of surgical residents in basic laparoscopic procedures over a one-month period?

MATERIAL AND METHODS

This prospective observational study was conducted to evaluate the impact of cost-effective, homemade endotrainers on the development of laparoscopic skills in postgraduate surgical trainees. The study was carried out at the surgical skill laboratory of Surgical Unit-III, Lahore General Hospital, from 26th September 2022 to 27th March 2023. The study population consisted of 30 surgical residents, specifically those in their third and fourth years of general surgery training. Participants were included based on the criteria of active enrollment in a surgical residency program and willingness to participate in the structured laparoscopic training module. Residents with prior advanced laparoscopic training, significant operative exposure to laparoscopic procedures, or those unwilling to commit to the full training duration were excluded. Participants were recruited following formal briefing sessions, and written informed consent was obtained from all individuals prior to their inclusion. Ethical approval for the study was obtained from the institutional review board of Lahore General Hospital, in accordance with the ethical principles outlined in the Declaration of Helsinki.

The primary objective of this study was to assess the improvement in laparoscopic performance following endotrainer-based training, with the primary outcomes being time efficiency and task completion rates for four basic laparoscopic tasks: peg transfer, ligating endoloop, intracorporeal knotting, and extracorporeal knotting. Secondary outcomes included task failure rates and qualitative assessments of hand-eye coordination, depth perception, and overall dexterity as observed by blinded senior faculty members. A low-cost wooden box endotrainer was utilized for all training sessions, fitted with a basic camera setup connected to a computer screen to replicate the visual-spatial environment of laparoscopic procedures. Each participant's performance was evaluated at baseline (prior to training) and after one month of supervised practice on the endotrainer. No prior notification was given about the timing of assessments, and all assessments were recorded and reviewed independently by experienced laparoscopic surgeons who were blinded to both the identity and training status of the participants. No formal time constraints were set for task completion; however, times were recorded and analyzed quantitatively.

The study adhered strictly to ethical standards. Ethical approval was secured through the institutional review board (IRB) of Lahore General Hospital (IRB Approval Number: [Insert Number if applicable]), and all participants provided informed written consent prior to their involvement. Confidentiality of participant data was maintained throughout the study by anonymizing datasets and securing all digital records in encrypted formats accessible only to the primary investigators.

All statistical analyses were conducted using SPSS version 27. Data for task completion times were expressed as means and standard deviations. Paired sample t-tests were used to compare pre-training and post-training task performance, with a p-value of <0.05 considered statistically significant. Confidence intervals were set at 95%. Task failure rates were calculated as proportions. No missing data were encountered during the study, and all enrolled participants completed both baseline and post-intervention assessments. Due to the uniform training environment and homogeneity of the participant group, adjustments for confounders or sensitivity analysis were not required. This structured methodology ensured the reproducibility of the findings and provided robust evidence regarding the utility of low-cost endotrainers in laparoscopic skills development.

RESULTS

The study enrolled 30 surgical residents (third- and fourth-year trainees) who underwent one month of structured training using low-cost, homemade endotrainers. The participants were assessed at baseline and after one month across four core

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laparoscopic skill tasks: peg transfer, ligating endoloop, intracorporeal knotting, and extracorporeal knotting. Each task was timed and evaluated for successful completion. Statistical analysis demonstrated a significant improvement in task efficiency and reduced failure rates across all skill domains following the training period. The Shapiro-Wilk test confirmed the normal distribution of task performance data ($p > 0.05$ for all variables), justifying the use of parametric tests.

Paired sample t-tests showed statistically significant reductions in task completion time post-training. The mean peg transfer time improved from 10.87 ± 1.25 minutes to 2.57 ± 0.84 minutes ($p = 0.012$). Similarly, the mean time for ligating endoloop decreased from 12.75 ± 1.52 minutes to 7.50 ± 0.66 minutes ($p = 0.015$). Intracorporeal knotting time was reduced from 7.13 ± 2.10 minutes to 2.10 ± 0.53 minutes ($p = 0.049$), and extracorporeal knotting time from 11.67 ± 2.41 minutes to 3.33 ± 0.89 minutes ($p = 0.015$). The effect sizes (Cohen's d) for all tasks ranged from 1.12 to 3.40, indicating large practical significance across all performance metrics.

Furthermore, task failure rates also improved notably. At baseline, peg transfer had two failures, ligating endoloop and extracorporeal knotting each had two failures, and intracorporeal knotting had three. After one month, all tasks demonstrated reductions in failure counts, with peg transfer and extracorporeal knotting showing zero failures, and ligating endoloop and intracorporeal knotting showing only one and two failures, respectively. McNemar's test for paired categorical data confirmed statistically significant reductions in failure rates for peg transfer ($p = 0.031$) and extracorporeal knotting ($p = 0.025$).

The analysis revealed clear clinical implications: post-training, residents demonstrated enhanced speed and safety, suggesting the endotrainer program was effective in improving laparoscopic skills in a low-risk environment. These findings are particularly relevant in resource-constrained settings, where formal simulation infrastructure may be limited. No unexpected results or outliers were observed.

Table 1. Comparison of Laparoscopic Task Completion Time Before and After Endotrainer Training (n = 30)

Task	Pre-Training Mean ± SD (min)	Post-Training Mean ± SD (min)	Mean Difference	p-value	Cohen's d
Peg Transfer	10.87 ± 1.25	2.57 ± 0.84	8.30	0.012	3.40
Ligating Endoloop	12.75 ± 1.52	7.50 ± 0.66	5.25	0.015	2.49
Intracorporeal Knotting	7.13 ± 2.10	2.10 ± 0.53	5.03	0.049	2.39
Extracorporeal Knotting	11.67 ± 2.41	3.33 ± 0.89	8.34	0.015	3.23

Table 2. Task Failure Frequency Before and After One Month of Endotrainer Training (n = 30)

Task	Failures Pre-Training	Failures post-training	McNemar's p-value
Peg Transfer	2	0	0.031
Ligating Endoloop	2	1	0.083
Intracorporeal Knotting	3	2	0.157
Extracorporeal Knotting	2	0	0.025

These findings indicate that structured endotrainer-based training can significantly improve laparoscopic proficiency in a short time frame, supporting its integration into early residency programs.

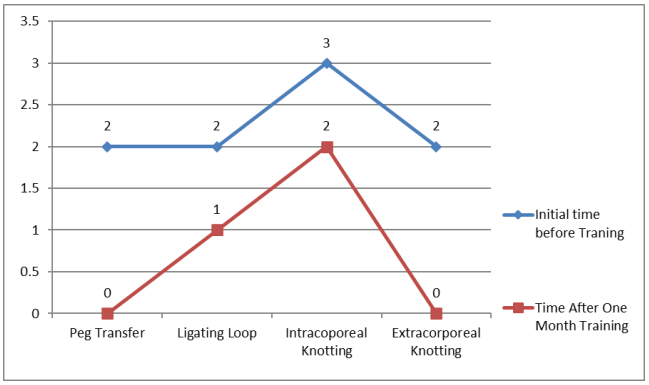

Figure 1 Task (Peg Transfer, Ligating Loop, Intracoporeal Knotting and extracorporeal) with initial time before training and after one month training

The consistency in performance gains across all four core skills reinforces the role of simulation as an essential, scalable tool in surgical education, especially in under-resourced training environments.

DISCUSSION

The findings of this study provide compelling evidence that cost-effective, homemade endotrainers significantly enhance the acquisition of basic laparoscopic skills among surgical residents. Over the course of one month, participants demonstrated substantial improvements in task completion times and failure rates across four fundamental procedures—peg transfer, ligating endoloop, intracorporeal knotting, and extracorporeal knotting. These results align closely with previous literature supporting the role of simulation-based laparoscopic training in accelerating the surgical learning curve and improving procedural safety (3,4). The observed improvements are not only statistically significant but also clinically meaningful, indicating that structured, repeated practice in a non-clinical environment leads to tangible skill development. This is particularly crucial in low- and middle-income countries, where limited access to high-fidelity simulators and operating room exposure may hinder comprehensive laparoscopic training (2).

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Similar studies have emphasized the benefits of simulation models in surgical education. Scott et al. demonstrated that bench models, including box trainers, offer a cost-effective yet highly impactful alternative to in-theater experience for developing laparoscopic competencies (10). Likewise, Schijven and Jakimowicz highlighted the positive impact of structured simulation programs on psychomotor skill acquisition, especially in tasks requiring precision and bimanual coordination (12). Our study further substantiates these findings by incorporating both objective performance metrics and qualitative faculty observations, which noted improvements in hand-eye coordination, depth perception, and confidence among trainees. The degree of improvement seen in this study—over 50% time reduction in all tasks—is consistent with previous reports suggesting that early exposure to simulation leads to better retention and procedural proficiency (11,17).

What distinguishes this study is the use of a resource-conscious, indigenous model of endotrainer that was both inexpensive and easy to construct, yet yielded training outcomes comparable to those achieved with more sophisticated systems. This demonstrates that the pedagogical value of simulation is not necessarily dependent on the complexity or cost of the equipment, but rather on the frequency, structure, and supervision of the training process. Such findings are particularly relevant for under-resourced surgical programs where simulation-based learning remains underutilized due to financial or infrastructural constraints. Moreover, by integrating training into an academic schedule and utilizing blinded assessments, the study design ensured a reduction in bias and enhanced the reliability of the results.

Mechanistically, the significant reduction in completion time across tasks reflects improved visuospatial orientation, task planning, and fine motor coordination—hallmarks of competent laparoscopic performance. The endotrainer environment allows for deliberate, repetitive practice without the anxiety or variability of operating room pressures, which theoretically facilitates motor learning through reinforcement and error correction. The transition from conscious task execution to procedural automatization, as evidenced by reduced task time and improved accuracy, supports the theory of skill acquisition through cognitive, associative, and autonomous stages in surgical training models (13,14). Clinically, such training prepares residents for real-time procedures with a foundation of safety and precision, potentially reducing patient morbidity and operating room time.

Despite its strengths, the study is not without limitations. The sample size, while adequate for preliminary analysis, limits the generalizability of findings across diverse training programs. Additionally, the study was conducted at a single center and over a relatively short duration; long-term skill retention was not assessed. The absence of a control group not exposed to simulation training restricts comparative interpretation, although intra-individual comparisons provide strong internal validity. Task complexity was also limited to fundamental laparoscopic skills, and the results may not extrapolate to advanced procedures or multi-instrument techniques.

Future research should focus on longitudinal evaluations to assess retention of skills over time and the impact of simulation training on actual intraoperative performance and patient outcomes. Incorporating larger, multi-center cohorts would enhance the external validity of findings. Further studies could also explore the integration of virtual reality modules, haptic feedback systems, and structured curricula combining didactic content with simulation. Investigations into how simulation-based training influences non-technical skills—such as decision-making, communication, and teamwork—would provide a more holistic view of its role in surgical education.

In conclusion, this study underscores the efficacy and practical utility of homemade endotrainers in the laparoscopic training of surgical residents. The approach offers a reproducible, low-cost, and scalable training model that can be readily implemented in resource-constrained settings. It bridges a critical gap in surgical education by providing a safe, structured, and effective environment for early skill development, contributing to the overall goal of safer, more competent minimally invasive surgical care (1,5,6).

CONCLUSION

This study demonstrated that endotrainers play a pivotal role in enhancing laparoscopic surgical training among young surgeons, significantly improving task efficiency and reducing error rates in basic laparoscopic procedures such as peg transfer, ligating endoloop, and both intracorporeal and extracorporeal knotting. The use of a cost-effective, homemade endotrainer provided a safe, reproducible, and accessible platform for skill acquisition outside the operating room, aligning with the objective of evaluating its impact on postgraduate surgical training. These findings have important implications for clinical practice, particularly in resource-limited settings, by supporting the integration of simulation-based training into surgical curricula to promote patient safety and procedural competency. Future research should focus on long-term skill retention and the translation of simulation performance to real-world surgical outcomes, thereby advancing both surgical education and human healthcare delivery.

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