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Simulation-based structured training for developing laparoscopy skills in general surgery and obstetrics & gynecology postgraduates

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Abstract:

BACKGROUND: Simulation-based training is an important strategy for skill development in a competency-based curriculum, especially so for laparoscopic surgery given its unique learning curve, need for practice, and patient safety concerns. The study was conducted for postgraduates in two surgical disciplines in a medical college tertiary care center. The study evaluates the acceptability and utility of structured simulation-based training for laparoscopic skills. Simulations provide deliberate practice in the leaner supportive environment.

MATERIALS AND METHODS: The educational intervention was carried out among the 16 postgraduates from year 2 and year 3 of general surgery and obstetrics and gynecology. A structured training and assessment module was designed and validated, and a 12-week structured training on laparoscopic box trainers was given to postgraduates under faculty guidance. Feedback from postgraduates and faculty was obtained using separate validated questionnaires. The pre- and post-training assessment scores were compared applying the Wilcoxon matched-pairs signed-rank (2-tailed) test using the SPSS Windows Version 20.0 (IBM Corporation).

RESULTS: Sixteen postgraduates participated in the study. The median satisfaction score of the postgraduates was 4 (range 3–5), a scale of a maximum of 5. The group identified faculty feedback, stepwise skills learning, supportive learning environment, and trainers' motivation as enabling factors in the training. The faculty observed that the trainees were effectively engaged. The group mean improvement scores in percentage were 40.08 for task 1, 42.08 for task 2, 43.13 for task 3, and 45.63 for task 4.

CONCLUSIONS: It is feasible to incorporate faculty-guided sessions of simulation training in basic laparoscopy skills for postgraduates in our setup. It is well accepted by the key stakeholders, and we recommend it to be incorporated in the formal training program.

Keywords:

Feedback, laparoscopy skills, simulation training, structured training

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Introduction

Laparoscopy surgery has modernized surgical therapy, and it has become an integral part of postgraduate training in surgical disciplines. Surgery has been traditionally taught applying Halstead's principle, i.e., *"see one, do one, teach one."* Laparoscopy surgery involves working with real-time images on the monitor screen using endoscopic instruments which are navigated and manipulated outside the line of operators and trainees vision to perform the indicated surgical tasks. Therefore, the trainee is unable to observe the surgeon's hands, the instruments, and operative outcomes simultaneously.

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The Halstedian principle does not hold good for laparoscopy training.

Developing competence in laparoscopy surgery necessitates acquisition of skills such as navigation and manipulation of endoscopic instruments with abdominal wall acting as the fulcrum, camera handling, depth perception, screen video-hand-eye coordination, and tissue holding with manipulations. Acquiring this set of skills requires a stepwise deliberate practice and is usually associated with a long learning curve which necessitates a structured training. The trainee should practise on simulators until they attain a benchmark level of performance before they are allowed to practise surgery on actual patients. Simulations provide an effective means of acquiring the laparoscopy skills in a nonthreatening environment with trainee's freedom to practise skills repeatedly without any issues of patient safety. Moreover, teaching laparoscopy skills is often challenging during the actual operations because of concerns for patient safety, varying complexity of cases, and extra time consumption in anesthetized patients. Noble *et al.*, 2015, found that a gap exists between residents' and attending surgeons' perception of residents' laparoscopic skills and comfort level in performing laparoscopic cholecystectomy.[1]

Surgical training in laparoscopy skills is going through a paradigm shift.[2] The early stages of skills development (*as per Dreyfus' model of skills acquisition, the stages of Novice and Advanced beginner*), practice, training, and assessment in simulated settings are desirable.[3] The simulation physical box trainers, the video trainers, and the virtual reality simulation have become an increasingly important part of the early stages of laparoscopy training; as it is safe, ethical, and repeatable alternative; it produces objective measures of performance; and allows real-time feedback to trainees.[4] The literature suggests that the structuring of training contributes to better learning of skills.[5] According to Pazin Filho and Romano, a simulation session is characterized by the presence of four core components, namely "*Exposure*" (also called briefing), i.e., introduction to the problem/task ahead; "*Sequence*," i.e., progressive escalation of complexity of tasks; "*Feedback*" during and/or after the simulation session; and "*Repetition*" for reinforcing and improving knowledge, skills, and performance.[6] The aim of our study was to evaluate the acceptability and effectiveness of structured simulation training for developing laparoscopic skills in the postgraduates of surgical disciplines.

Materials and Methods

Study design and setting

This quasi-experimental pre- and post-test design study was conducted in the general surgery endo skills laboratory at People's Medical College and Research Centre, Bhopal (Madhya Pradesh), India.

Study participants and sampling

A total of 16 postgraduates, general surgery (8) and obstetrics and gynecology (8), participated voluntarily in the study. Ten faculty members voluntarily participated in the study.

Material resources

- Simulation box trainers: Two laparoscopy box trainers consisting of a training box, mounted on a table trolley with a webcam, display monitor, and a fluorescent fiber-optic light source for illuminating inside the box [Figure 1]. Video-box trainers include a box with a lid and holes cut on the lid for the trocar's insertion. A digital camera provides video output to a monitor on which the trainees watch their own movements while performing the teaching task.[7] A box trainer utilizing the camera, screen, light source, and endoscopic instruments enables developing laparoscopy skills.
- Laparoscopy instruments: Atraumatic grasping forceps (both jaw opening), grasping forceps curved left (both jaw opening-Maryland Dissector), scissors curved left (both blades opening-Metzenbaum), and modular needle holder.

A training module was designed and validated. The study group was given 12-week structured training on laparoscopic box trainers under direct faculty supervision. The four tasks [Figure 1] designed for the training were as follows. Timing for each task began when the trainee touched the first object. Timing ended upon release of the last object.

- Task 1: Ball transfer – arranging the beads in a linear pattern, T pattern, and circle
  In this task, the trainee picked up the balls with the nondominant hand first, made a mid-air transfer to the dominant hand, and placed them in a socket to form two linear row patterns, and then in a "T" or a circle pattern
- Task 2: Ring transfer – placing the rings on the pegs-on straight and curved and disassembling them
  In this task, the trainee grasped each ring with the nondominant hand and transferred the object mid-air to the dominant hand. Then she/he placed the ring on the straight peg on the opposite side of the pegboard. Once all eight rings were transferred to the opposite side of the board, the trainee reversed the process and first grasped each ring with the dominant hand, transferred mid-air to nondominant hand, and placed on the original side of the pegboard. A penalty was assessed if an object was dropped outside of the field of view or depending on the angle the trainee could no longer retrieve the object. A similar sequence was

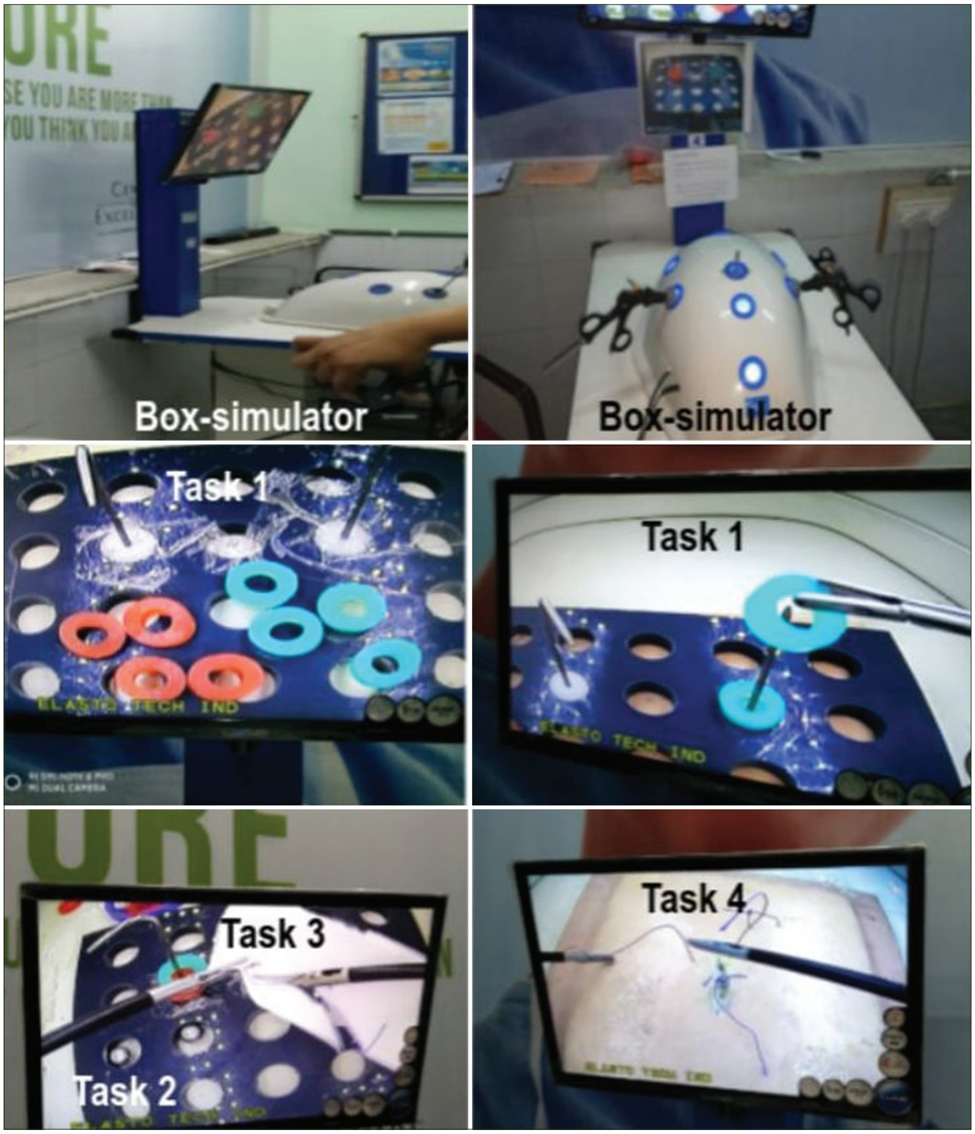

Figure 1: The four tasks in simulation-based structured training

repeated for the curved pegs, increasing the difficulty level

- Task 3: Precision cutting – cutting a semicircle on a piece of paper
  Using the Maryland dissector in one hand, the trainee maintained traction to the paper sheet, placing it at the best possible angle to the cutting hand. On the other hand, using endoscopic scissor, the trainee cut along the premarked semi-circle until it was completely removed from the sheet. Deviations of the cuts outside or inside the marked semicircle were counted as a penalty
- Task 4: Simple suture and knot tying
  For this task, the trainee was required to place a simple suture through the two margins of the incision in the sponge pad and then tie a simple triple throw surgeon's knot using endoscopic needle holder in dominant hand and grasper forceps in the other to close the incision.

Data collection tool and technique

A structured assessment pro forma was developed based on a validated pro forma selected from the literature.[8,9] This was peer reviewed and validated. A global rating scale pro forma for assessing generic skills (tasks 1 and 2) Table 1; and a checklist pro forma for the procedure-specific skills (task3 and task 4) was developed.

The checklist for precision cutting "Semi-circle" was based on stepwise skills in chronological succession: picks up the proper instrument, holding the instrument in the dominant hand, introducing the instrument in the simulator, rotational movements used, ambidexterity, control of the hand force while cutting, sharp and cuts clean, and precision on the cutting limits. A score of 1 was marked for each of the correctly performed skills to complete the task, and finally, the overall score was

Table 1 Rating Scale: Task 1 and Task 2 (maximum score=6 variables × score 5=30)

Skills	Rating score for the performance of tasks				
	1	2	3	4	5
Navigation of instrument (dexterity)	Often exhibits doubtful or clumsy movements		Exhibits occasional clumsy movements		Fluency in the use of instruments, no clumsy or cumbersome movements
Centering of the instrument tip on-screen (visibility)	Instrument tip often out center and sight		Instrument tip mainly in the center, sometimes out of sight		Instrument tip continuously in center and well insight
Depth perception (3D/2D orientation)	Often misses out the aimed object, spread out swings, aimed object, slow to correct		Sometimes misses out the aimed object, corrects immediately		High precision to grasp the aimed object
Object handling	Rough, poor grasper control, often slips the object		Grasping reasonably well		Smooth handling of objects. Good grasping and rarely slips the object
Ambidexterity	Only uses the dominant hand		Skillfully uses both hands with some harmonizing actions		Skillfully uses both hands with good harmonizing actions
Autonomy	Unable to complete able to complete the task even with major guidance		Able to complete the task with moderate guidance		Able to complete the task independently, no guidance required

2D=Two-dimensional, 3D=Three-dimensional

calculated. The constructive feedback by the faculty guide was given based on direct observation and entered in the pro forma.

Similarly, the checklist for suturing and knot tying was based on stepwise skills in a sequence of: picks up the proper instrument, holding the instrument in the dominant hand, introducing the instrument in the simulator, the pattern of needle holding (right angle) in the instrument, control of the hand force on the needle holder, the needle enters the pad at right angles, at an optimum distance (~3 mm) from the cut edge, movement of the needle at entry and exit through the sponge pad using the axis of the curve of the needle, formation of the loop for knot tying, square knots on one side of the suture line, and suture cut at the optimum length.

Self-efficacy questionnaire

A validated self-efficacy questionnaire on 5-point Likert scale was designed and validated. The postgraduates were required to mark the most appropriate response on the scale of 5 (where 5 was the highest, and 1 being the lowest). The statements were framed in cognitive (3), psychomotor (4), and affective domain (5). A separate validated questionnaire for feedback from the postgraduates and faculty was designed.

Implementation of the skills training program

The study was conducted after the approval from the Institutional Ethics Committee: IEC No-2019/05 Letter Ref. no. PCMS/OD/2019/591 dated April 16, 2019. All the participants signed the informed written consent prior to participation. Two faculty trainers of the research team conducted the training sessions.

The training began with four interactive lectures and demonstrations: "The Principles of Laparoscopic Surgery;" "Orientation to the Operation theatre for Laparoscopy;" "Know your simulator and instruments;" and "Application and role of Laparoscopy in the current surgical practice." A pretest was conducted before the technical skills training. The directly observed hands-on training was then implemented batch wise. The trainers used the "DOAP" (demonstrate-observe-assist-perform) method for the skills training. The trainers directly observed trainees while practicing skills on the simulators and provided constructive feedback. The training was for 1 h per trainee every day for 12 weeks. Each training session was marked on the validated structured pro forma. A posttest was conducted for technical skills, and the postgraduate's feedback was obtained using the validated self-efficacy pro forma, and a validated general feedback was obtained at the end of the training. Feedback from the faculty was obtained at the end of the course.

Data collection and Statistical Analysis: The Likert scale items in the feedback forms were analyzed using median and range and the open-end items using content analysis. The difference in group mean scores between the pre and posttests for each of the four tasks was compared and taken as a measure of acquisition of the laparoscopy skills. The pre- and posttest difference was also calculated as a percentage improvement score. The nonparametric Wilcoxon matched-pairs signed-rank (2-tailed) test was used to calculate the statistical significance using the IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY (IBM Corporation). $P < 0.05$ was considered statistically significant.

Ethical consideration

The participation of postgraduates was voluntary, and the participants signed the informed written consent before enrolment in the study. The participants were free to withdraw from the study at any stage. The data confidentiality and anonymity were adhered during all the stages of the study and its publication.

Results

The study group consisted of 16 postgraduates, 12 females and 4 males. Eight were from general surgery, and obstetrics and gynecology each. The three postgraduates were dominant left-handed users and the remaining 11 dominant right-handed.

Feasibility and acceptability

The implementation of the simulation-based structured training program in the prevailing time schedule was feasible and acceptable to postgraduates and faculty. The postgraduates were satisfied with the skills training [Figure 2]. The median satisfaction score reported by the postgraduates was 4 (range: 3–5). The postgraduates perceived the training to be useful and effective for acquiring the psychomotor skills [Figure 3]. The content analysis of the open-end items of the feedback questionnaire of the postgraduates identified trainer feedback (48.2% respondents), stepwise skills learning (18.5% respondents), supportive learning environment (22.2% respondents), and trainers' motivation (11.1% respondents) as enabling factors for the training program [Figure 4].

The faculty perceived effective engagement of postgraduates in skills training (median score of 5, range: 4–5 on the scale of 5). The content analysis of the open-end items of the faculty feedback questionnaire identified stepwise skills training (16.7% respondents), effective sensitization (25% respondents), supervised training (25% respondents), and motivation of postgraduates (33.3% respondents) as enabling factors for the training program [Figure 5]. Managing time with commitments of workplace was a constraint expressed by the majority of the teachers and postgraduates both.

Pre- and post-test comparison

The study group percentage improvement score in the pretest–posttest design [Table 2] was task 1: 40.83%, task 2: 42.08%, task 3: 43.13%, and task 4: 45.63% at the end of the 12 weeks. The group mean improvement score were 12.25 ± 3.72 for task 1, 12.63 ± 3.96 for task 2, 4.31 ± 0.79 for task 3, and 4.56 ± 0.73 for task 4, and applying the Wilcoxon matched-pairs signed-rank (2-tailed) test, the improvement was statistically significant.

Discussion

In the present surgical practice, widespread applications

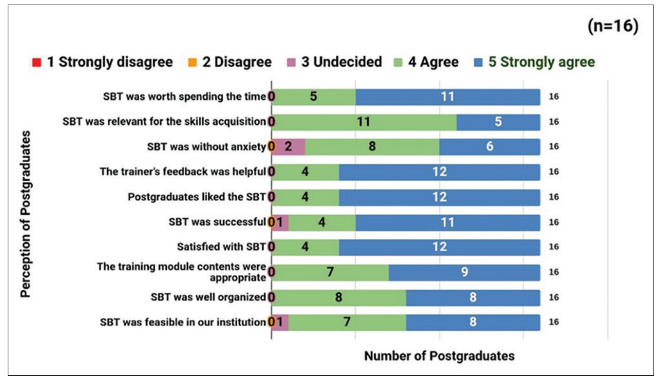

Figure 2: Perception of postgraduates on a Likert scale of 5: feedback on simulation-based structured training

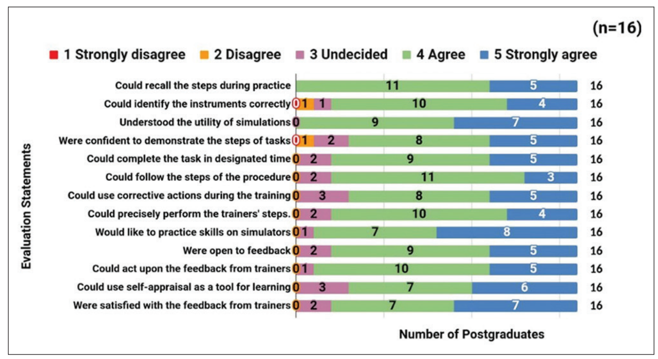

Figure 3: Postgraduates' self-efficacy evaluation

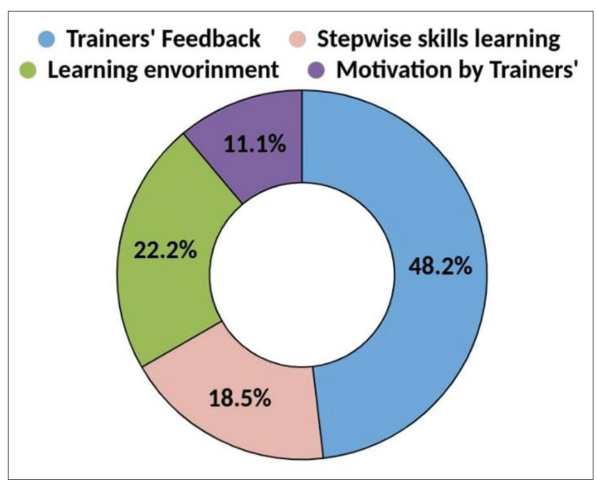

Figure 4: Postgraduates' feedback: content analysis of the open-end responses for the training

Table 2: "Pre-post" group improvement score (*n*=16) for the laparoscopy skills acquisition among the postgraduates

Laparoscopy skills	Task 1	Task 2	Task 3	Task 4
Mean improvement score (d)	12.25±3.72	12.63±3.96	4.31±0.79	4.56±0.73
Wilcoxon matched-pairs signed-ranks test (*Z*)	3.5	3.5	3.6	3.6
Percentage improvement score (%)	40.83	42.08	43.13	45.63

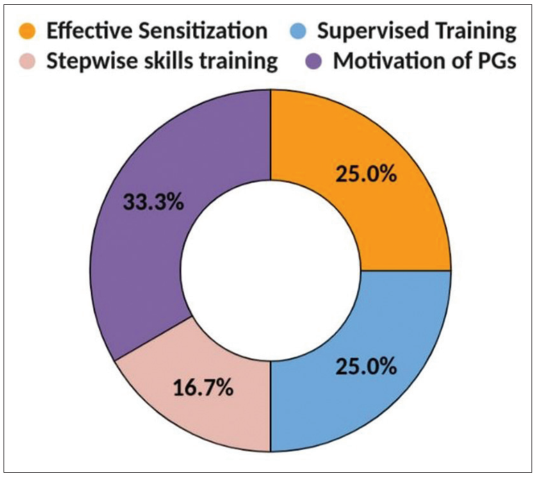

Figure 5: Faculty' feedback: content analysis of the open-end responses for the training

of laparoscopy surgery necessitate incorporating the laparoscopy skills training in the traditional postgraduate curriculum. The laparoscopy skills training is fundamentally a proficiency-based training initially on simulators, before the learners move on to the stage of performing actual laparoscopy surgery on patients under supervision. The focus should be to effectively implement deliberate practice, highlighting the principles of part-task training, proficiency-based training, and overtraining.[10] Learning technical and nontechnical skills outside the operating room has become an essential part of surgical training.[4] Simulation is a powerful tool to improve own capacities for laparoscopy skills.[11] Postgraduates need opportunities for regular, deliberate practice on simulators under faculty guide with constructive developmental feedback.[12] The apprentice-tutor model of surgical training "see one, do one, teach one" has lost favor to a variety of simulation methods that, while improving the skills of trainee, has zero risk to patient.[13] The present study was a change in our institute toward structured simulation training for developing laparoscopy skills in postgraduates. It was an endeavor to integrate this structured validated simulation training with the ongoing postgraduate training program of the two disciplines and to assess the learning outcomes in terms of skills acquisition at the end of training.

In this study, the postgraduates performed two basic tasks (bead transfer, and peg-transfer) and two procedural skills (cutting, and suturing) under faculty trainers. The basic tasks were designed to teach generic laparoscopy skills (instrument navigation and manipulations, depth perception, video-hand-eye-coordination, and dexterity). The trainees were directly assessed and immediate constructive feedback was provided toward skill development. The postgraduates perceived the training to be useful and effective, and the perception score of their self-efficacy is indicative of their confidence in skills improvement. They expressed that faculty feedback was the most helpful factor in learning technical skills, and this only reiterates the well-known effect of timely feedback on learning. The postgraduates identified trainer feedback (48.2% respondents), stepwise skills learning (18.5% respondents), supportive learning environment (22.2% respondents), and trainers' motivation (11.1% respondents) as facilitating factors for the training program in our study. Assessment and feedback has been shown to be a valuable asset to surgical training.[14] Our study demonstrates that simulation-based structured laparoscopy skill training was feasible and acceptable to the postgraduates and faculty in our institute. The faculty reported effective engagement of postgraduates in skills training. The postgraduates after the 3 months of structured simulation training using box trainers had statistically significant improvement in the group mean scores for all the four tasks. The group mean percentage improvements in the scores were 40.83, 42.08, 43.13, and 45.63 for the tasks 1, 2, 3, and 4, respectively. This could be attributed to the outcome of the training program. We have used a global rating scale for assessment of generic skills and checklists for task-specific assessment and found both to be useful. However, Scott *et al.* have shown that checklists do not add any additional value and less reliable than global rating scales.[15] Earlier studies have shown that simulation allows the learners to practice technical skills in a safe and stress-free environment, thereby decreasing the learning curve.[16] Computer-based simulations are effective for training and evaluation of surgical skills.[17] A systematic review of randomized control trials to examine the effectiveness of simulation-based training to develop laparoscopic surgery skills recommends "simulation-based training is an effective way to teach laparoscopic surgery skills, increase translation of laparoscopic surgery skills to the operating rooms, and increase patient safety."[18] A study from GS Seth Medical College and KEM hospital, Mumbai, demonstrated that short-term courses improve the laparoscopy skills of the trainee and that using box-endo trainers can transform the didactic training into objective and competency based.[5] Other studies have also reported the use of box trainers to be effective in laparoscopy skill improvement and retention, especially in training basic laparoscopic skills.[19] Shah *et al.* in their study on anesthesia postgraduates found the effectiveness of structured training for retention of procedural skills to be good.[20] The present study supports the findings of earlier researchers. Our finding of significant improvement in the generic and specific laparoscopic skills on the simulator in the study group after the training is similar to that reported by Supe *et al.*[8] and Muthammal and Ramprasath.[21]

It is expected that the postgraduates shall be able to apply the skills learned during this short-term training while they are assisting/operating laparoscopic procedures in actual patients. Structured and supervised training on simulators will perhaps prepare them for better learning outcomes when combined with traditional training. Appleton and Huguelet reported simulation to be an effective teaching tool for residents without becoming a burden on a department.[22] Simulators have been shown to provide better laparoscopic surgery skills training.[23] Torricelli *et al*. suggested that a short period of training with laparoscopic stimulators improves laparoscopic surgical skills.[24] Papanikolaou *et al*. suggested that teaching hospitals should introduce training programs using laparoscopic simulators with standardized and reproducible tasks.[25]

Managing time with commitments of workplace was a constraint expressed by the teachers and postgraduates. However, a majority of them recommended that the training be formally included in the postgraduate training program of the two disciplines. The transferability of skills to actual settings remains an important aspect to be studied. Long-term study is required to understand the effect of combined learning from simulation and conventional training. We recommend further research to correlate the transfer of the skills acquired in simulation to the actual laparoscopy surgery.

Limitation and recommendation

Although the small sample size was a limitation, we felt it was adequate to explore the feasibility and acceptability of skills learning on the simulators. We recommend further research with a larger sample size to study the effectiveness of such training programs and the transfer of basic laparoscopy skills to actual practice.

Conclusions

Simulation-based structured laparoscopy skills training was feasible and acceptable in our institute and could be integrated into the ongoing residency training program. The postgraduates demonstrated a significant improvement in generic and procedure-based laparoscopy skills on box simulator. The postgraduates perceived direct observation by faculty and immediate feedback as the most helpful factor in progressive acquisition of skills. Short-term structured simulation in the traditional postgraduate curriculum helps in shaping competent laparoscopic surgeons.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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