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EDUCATION AND TRAINING

Laparoscopic virtual reality simulator and box trainer in gynecology

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ABSTRACT

Objective: To investigate whether a virtual reality simulator (LapSim) and traditional box trainer are effective tools for the acquisition of basic laparoscopic skills, and whether the LapSim is superior to the box trainer in surgical education. *Methods:* In a study at Ege University School of Medicine, Izmir, Turkey, between September 2008 and March 2013, 40 first- and second-year residents were randomized to train via the LapSim or box trainer for 4 weeks, and 20 senior residents were allocated to a control group. All 3 groups performed laparoscopic bilateral tubal ligation. Video records of each operation were assessed via the general rating scale of the Objective Structured Assessment of Laparoscopic Salpingectomy and by operation time in seconds. *Results:* Compared with the control group, the LapSim and box trainer groups performed significantly better in total score ($P < 0.01$ and $P < 0.01$, respectively) and time ($P = 0.03$ and $P = 0.01$, respectively). There were no differences between the LapSim and box trainer groups. *Conclusion:* Novice residents who trained on a LapSim or box trainer performed better live laparoscopies than residents who trained via standard clinical surgical education. Training with a virtual reality simulator or box trainer should be considered before actual laparoscopic procedures are carried out.

1. Introduction

Laparoscopic surgery has had a fundamental role in gynecology over the past 2 decades [1]. On the one hand, it has not only reduced mortality and yielded better cosmetic results, but also given patients an opportunity for a shorter recovery time [2,3]. On the other hand, laparoscopic surgery presents some well-known technical complexities, requiring the ability to switch from 3D to 2D views, the handling of long rigid instruments that amplify any tremors or movement, adjustments for impaired tactile feedback, and familiarity with the fulcrum effect [1,4,5].

It is well known that decision making is superior to dexterity in terms of open surgery success; however, the latter is more important in laparoscopy [6]. These technical difficulties can be overcome by gaining novel and unique psychomotor skills; however, this is time consuming and requires a convenient teaching curriculum [7,8]. Moreover, patient safety and quality control mechanisms have come into prominence; when these events merge with increasing financial constraints, the efficacy of surgeons and cost-effectiveness of the procedures become more important in the operating room [9,10]. For these reasons, training in a pressure-free environment with virtual reality simulators and box trainers has become popular in the field of laparoscopic skill improvement.

The box trainer is a relatively inexpensive and multifunctional device that includes real laparoscopic instruments to give the student the option to train on animal parts and synthetic materials [11,12]. Newer virtual reality systems such as LapSim (Surgical Science, Gothenburg, Sweden), which provides a considerable facility for both training and assessment, facilitate the replication of tasks such as cutting, grasping, and suturing [13–16]. However, these systems are relatively expensive and also require regular maintenance costs.

The primary aim of the present study was to investigate whether the LapSim virtual reality simulator and traditional box trainer are effective tools in the acquisition of laparoscopic psychomotor skills by comparing the LapSim and the box trainer with classic surgical education. A secondary aim was to test whether the LapSim virtual reality simulator is superior to the traditional box trainer in surgical education.

2. Materials and methods

The present prospective, randomized, blind, controlled trial was carried out between September 1, 2008, and March 31, 2013, among 60 gynecologic specialty residents at Ege University School of Medicine, Izmir, Turkey, who had no experience with the LapSim or box trainer. Approval for the study was obtained from the ethics committee of the university, and informed consent was obtained from residents and patients.

The obstetrics and gynecology specialization program takes 5 years in Turkey. Twenty of the participants were senior residents (postgraduate year 5); 40 were first- and second-year residents (postgraduate years 1–2). The senior residents comprised the control group and had previous experience with simple laparoscopic operations performed by a single hand, such as diagnostic laparoscopy and/or assisting senior colleagues (clinical standard education). The remaining 40 residents were randomly assigned to the LapSim group or the box trainer group. The training was spread out over a period of 5 weeks. During the first week, all groups received teaching in basic laparoscopy, laparoscopic bilateral tubal ligation (BTL), and the purpose of the study. During the

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subsequent 4 weeks (1 hour per week), the LapSim group and the box trainer group completed separate training sessions. The control group did not receive any further training.

After the training program, all residents performed their first laparoscopic BTL and were supervised by an experienced laparoscopic surgeon. All procedures were performed from the left side in order to standardize the comparison of the residents' performances. Patients with a severe systemic disorder, previous open abdominal surgery, a body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters) of less than 18 or more than 30, or other factors that might have potentially negative effects on the surgical procedure were not included in the study.

The pneumoperitoneum was created via Veress needle through the umbilicus, and a 10-mm umbilical trocar for the optic system and 5-mm bilateral lower abdominal trocars for instrumentation were inserted. The ampullary–isthmic junction was identified with grasping forceps through the ipsilateral lower abdominal trocar, and the ampullary–isthmic junction was coagulated and cut with bipolar forceps and scissors through the contralateral lower abdominal trocar. Residents held both lower quadrant instruments and the supervising surgeon held the camera. Supervisors were not allowed to hold the lower quadrant instruments, and a researcher was responsible for observing and recording the procedure.

To evaluate technical performance and operation time, the raw video records were assessed by 2 independent observers, who were blind to the residents' identities. For technical performance, the "general skills items" of the Objective Structured Assessment of a Laparoscopic Salpingectomy (OSA-LS)," comprising a 5-item, general rating scale (economy of movements, confidence of movement: instrument handling, economy of time, respect for tissue, flow of operation/operative technique) and a 5-item, task-specific rating scale [17], was used (Table 1). The OSA-LS has been validated in a previous study [18]. The total score for each operation was determined by averaging the scores given by both independent observers. The operation time began when the resident held both instruments and ended when both lower abdominal trocars were taken out.

The LapSim virtual reality simulator is a PC-based system that includes a 19-inch monitor and a laparoscopic interface module with 2 instruments and a foot switch. The software is run on a dual-processor Pentium D 3-GHz computer with 1 GB of RAM and a GeForce 6800 graphics card using Windows XP Professional (Microsoft, Redmond, WA, USA) (Fig. 1).

LapSim provided training in 8 tasks (Fig. 2). Task 1, camera navigation: center randomly appearing balls in the camera view. Task 2, instrument navigation: indicate emerging balls by both instruments sequentially. Task 3, coordination: touch randomly appearing virtual spheres (1 hand holds the camera, and the other hand manipulates the instrument). Task 4, grasping: grasp, stretch, and remove virtual blood vessels. Task 5, cutting: 1 instrument grasps a virtual vessel to identify the target zone, while the other instrument cuts the vessel through the target zone with an ultrasonic dissector. Task 6, lifting and grasping: 1 instrument lifts a virtual object to visualize a hidden needle, while the other instrument grasps and carries the needle to a target zone. Task 7, suturing: suture the tissue-like target zone and tie the knot. Task 8, dissection: 1 instrument grasps and stretches an object to allow the other instrument to dissect a small vessel-like tissue by using monopolor cautery.

The box model trainer was constructed from dark plastic in the shape of a rectangular prism ($45 \times 30 \times 25$ cm). Five holes were cut out for the camera and trocars. The right side of the box trainer was left open for placement of the training tools (Fig. 3). The box trainer provided training in 7 tasks (Fig. 4). Task 1, excise a drawn circle with a 4-cm diameter from a thin sponge media directly on a line. Task 2, move pegs on a board. Task 3, cut the outer balloon of 2 balloons without rupturing the inner balloon, which is filled with ultrasound gel for mimicking ovarian cyst enucleation. Task 4, grasp and throw beans

Table 1
Assessment chart for general skills of OSA-LS.

Item	OSA-LS score 1	2	3	4	5
Economy of movements	Many unnecessary moves		Efficient motion, but some unnecessary moves		Maximum economy of movement
Confidence of movement/instrument handling	Repeatedly makes tentative or awkward moves with instruments		Competent use of instruments, although occasionally appears stiff or awkward		Fluid moves with instruments and no awkward
Economy of time	Too much time taken to perform sufficiently		Intermediate time taken to perform sufficiently		Minimal time used to perform sufficiently
Respect for tissue	Frequently uses unnecessary force on tissue, risk of damage by inappropriate use of instruments, or instruments often out of sight		Careful handling of tissue but occasionally risk of (minimal) damage, or instruments out of sight		Consistent handling of tissues appropriately with no risk of damage, instruments always in sight
Flow of operation/operative technique	Imprecise, wrong technique in approaching the operative interventions, or constant supervisor corrections		Careful technique with occasional errors or little supervisor correction		Fluent, secure, and correct technique in all stages of operative procedure, no supervisor corrections
Total score					

Abbreviation: OSA-LS, Objective Structured Assessment of a Laparoscopic Salpingectomy.

Fig. 1. The LapSim virtual reality simulator.

into a small box. Task 5, peel a mandarin orange. Task 6, suture a sponge and tie the knot. Task 7, introduce an epidural catheter into a piece of intravenous infusion tube.

Data were analyzed by using SPSS version 15.0 (IBM, Armonk, NY, USA). Because the data were nonparametric, the Kruskal–Wallis test was used to compare differences among the groups. For significant parameters, the Mann–Whitney *U* test was used. Significance was set at a *P* value of less than 0.05.

3. Results

The demographic characteristics of each study group are shown in Table 2.

The median (range) total score of the general skills part of the OSA-LS rating scale was 17 points (15–19 points) in the LapSim group, 17 points (16–18 points) in the box group, and 11.5 points (10–14 points) in the control group. The median operation time to complete the procedure was 340 s (260–400 s) in the LapSim group, 340 s (270–430 s) in the box group and 425 s (320–530 s) in the control group.

There was no difference between the LapSim and box trainer groups in terms of total score and operation time ($P = 0.71$ and $P = 0.56$, respectively). Compared with the control group, however, the LapSim group performed significantly better in total score and operation time ($P < 0.01$ and $P = 0.03$, respectively). In addition, the LapSim group scored significantly better on economy of movements ($P < 0.01$), confidence of movement/instrument handling ($P < 0.01$), economy of time ($P < 0.01$), and respect for tissue ($P < 0.01$) compared with the control group.

Similarly, the box trainer group did significantly better work in terms of total score ($P < 0.01$) and operation time ($P = 0.01$) compared with the control group. Similar to the LapSim group, the box trainer group performed significantly better in economy of movements ($P < 0.01$), confidence of movement/instrument handling ($P < 0.01$), economy of time ($P < 0.01$), and respect for tissue ($P < 0.01$) compared with the control group. By contrast, there were no differences in the score for flow of operation/operative technique among the 3 groups.

4. Discussion

Despite the fact that laparoscopic surgery has an increasing role in gynecologic procedures, there has been little increase in the number of programs teaching laparoscopic skills. The “see 1, do 1, teach 1” method has been used in open surgery practice for a long time; however, because it takes excessive time and effort, this method cannot be applied to laparoscopy training [8]. Moreover, it carries serious risks in terms of legal and ethical concerns regarding patient safety, malpractice, surgeon efficiency, and operating room efficiency [19,20]. Owing to these concerns, the concept of modern surgical training has begun to change and has shifted, especially in laparoscopic surgery, from the “see 1, do 1, teach 1” method to practicing outside the operating room prior to actual human operations.

Both traditional box trainers and new-generation computer-based virtual reality simulators have long been used for the acquisition of basic laparoscopic skills. Although the effects of these systems have been demonstrated in a laboratory environment, studies showing their beneficial effects in real gynecologic operations are scarce [18,21–24]. Most primary studies compared the effects of these systems with those of control groups including medical students or surgical residents [22,24]. In addition, most of them evaluated post-training performance in a laboratory curriculum or during animal procedures, or on a virtual reality simulator [1,20,22,24,25]. For instance, Reznick et al. [14] randomized medical faculty students into virtual reality, box trainer, and control groups and assessed their performance on anesthetized pigs. They found

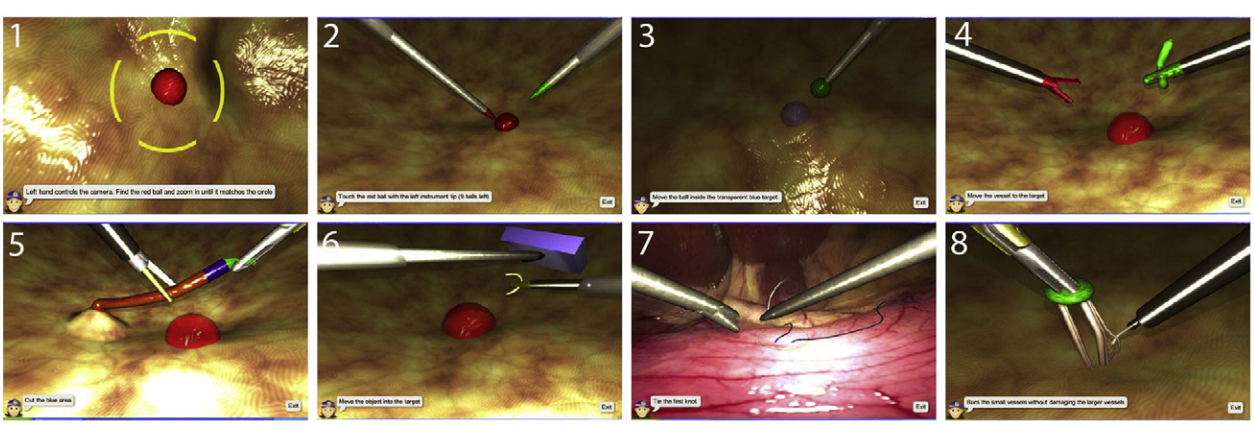

Fig. 2. The 8 LapSim tasks. Task 1, camera navigation; task 2, instrument navigation; task 3, coordination; task 4, grasping; task 5, cutting; task 6, lifting and grasping; task 7, suturing; task 8, dissection.

Fig. 3. The box trainer with trocars. The right side of the box trainer was left open to enable the training tools to be placed inside.

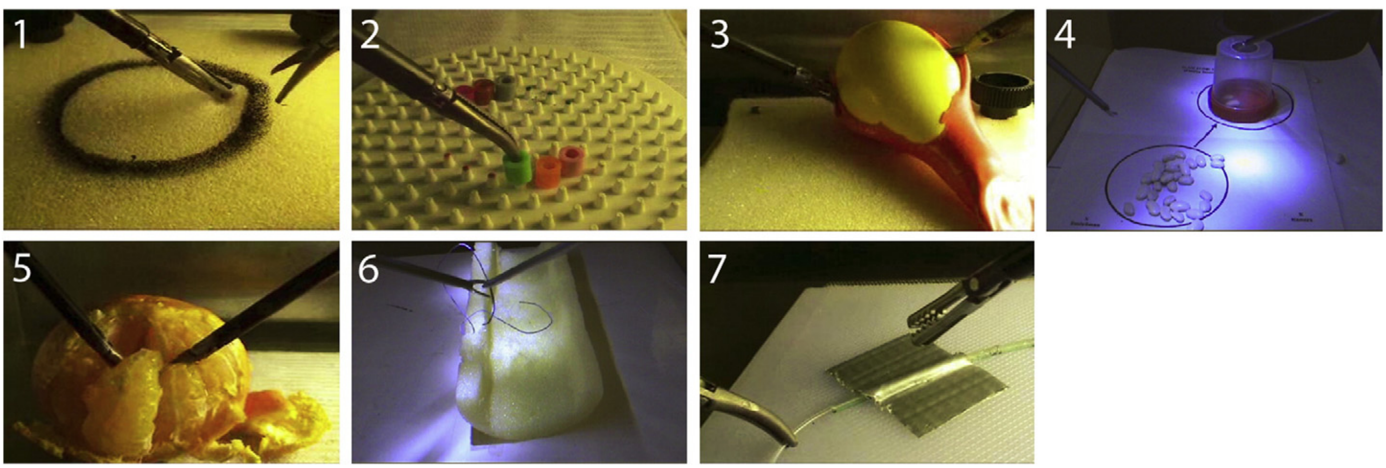

Fig. 4. The 7 box trainer tasks. Task 1, cutting out a drawn circle of a sponge; task 2, moving pegs on a board; task 3, simulating an ovarian cyst enucleation; task 4, grasping and throwing beans into a small box; task 5, peeling a mandarin orange; task 6, suturing; task 7, introducing an epidural catheter into a tube.

that virtual reality training was more effective than box training [14]. In another study, after their baseline laparoscopic skills were determined on a box trainer model, 24 novices were trained by different methods and reassessed on the box trainer [1]. There were no significant differences between the LapSim and box trainer groups [1].

Recently, other scientific research has compared virtual reality simulators with classic surgical education. One study has suggested that training with a virtual simulator has significant advantages over classic surgical education [18]. To the best of our knowledge, however, no previous study has compared the effectiveness of a virtual reality simulator and a box trainer with classic surgical education on operating room performance in gynecology.

Table 2
Demographics of the 3 study groups.

	LapSim group (n = 20)	Box trainer group (n = 20)	Control group (n = 20)
Age, y	25.5	26	29.5
Female:male	6:14	5:15	4:16
Dominant hand (R:L)	18:2	17:3	19:1
Previous laparoscopic experience	No	No	Yes
Previous LapSim experience	No	No	No
Previous box trainer experience	No	No	No

The present results suggest that both modalities are more effective than classic surgical education and that neither has superiority over the other. It may be proposed that, because box trainers provide tactile sensation to practitioners, they are superior to virtual reality simulators, especially with regard to the “respect for tissue” item of the OSA-LS. However, there was no difference between the LapSim group and the box trainer group with respect to tissue or in economy of movements, confidence of movement/instrument handling, and economy of time. The operation times for both the box trainer and the virtual reality groups were significantly better than those of the control group. However, this might not reflect clinical significance because the operation times for all groups were short. Indeed, further studies are needed to investigate the clinical significance of operation time in more complex procedures.

The control group in the present study included senior residents who had experience in simple laparoscopy and who were ready to perform their first laparoscopic BTL according to classic surgical education. In the classic surgical education program of the study institute, residents assist their senior colleagues in basic and advanced laparoscopic procedures at the end of their fourth year. Residents start to perform laparoscopic procedures such as BTL, ovarian cystectomy, salpingectomy, and salpingo-oophorectomy under the supervision of senior colleagues at the beginning of their final year. They also assist senior colleagues in more advanced laparoscopic surgeries such as hysterectomy, myomectomy, and oncologic surgery in the second half of their final year.

However, the amount and nature of the operations that they encounter change from resident to resident over a certain period of time.

Participants in the LapSim and box trainer groups performed their laparoscopic BTL operations immediately after their training programs finished. However, the time interval between the laparoscopic BTL operation and the last laparoscopic operation for residents in the control group was not determined in the study. These conditions may be contributing factors to the better performance of the LapSim and box trainer groups compared with the control group. The small sample size of the present study is another limitation. In addition, a follow-up future study might include another study group that would incorporate classic clinical education with a pre-operating training program.

After the end of the present study, the clinical surgical education program was revised in order to incorporate the results. All residents now complete the pre-operation room training before becoming an assistant in a real operation.

As seen in other studies and the present trial, both virtual reality simulators and box trainers are more effective than classic surgical education for basic gynecologic procedures. In addition, according to the present trial, neither the virtual reality simulator nor the box trainer has any superiority over the other. Because the box trainer is cheap and easy to maintain and replace, however, it would seem to present the initial option for trainers.

In summary, we suggest that, resources permitting, all laparoscopic training hospitals should construct a laparoscopic training laboratory that includes a traditional box trainer or both a box trainer and a virtual reality simulator.

Conflict of interest

The authors have no conflicts of interest.

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