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and Other Interventional Techniques

Prospective randomized controlled trial of laparoscopic trainers for basic laparoscopic skills acquisition

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Abstract
Background: Laparoscopic surgery requires a different set of skills than traditional open surgery. The acquisition of basic laparoscopic skills may help novices when learning laparoscopic procedures. This study tested the hypothesis that the combination of virtual reality and box trainers leads to better basic laparoscopic skill acquisition than either method alone or no training.
Methods: A randomized control trial involving preclinical medical students with no prior operative experience was performed. The students were grouped according to four training methods: virtual reality training, inanimate box training, a combination of both, and no training (control). The pre- and posttraining scores for four skills in the porcine laboratory were the metrics chosen for this study.
Results: A total of 65 students participated in this study. There were no differences among any of the pretraining scores ($p > 0.05$). The posttraining times differed between the four groups. Post hoc analyses showed statistically significant differences ($p < 0.05$) between the participants trained with both trainers and the control subjects.
Conclusions: Our data demonstrate that the combination of virtual reality training and inanimate box training leads to better laparoscopic skill acquisition than either training method alone or no training at all. Optimal preclinical laparoscopic training should incorporate both virtual reality trainers and inanimate box trainers.

Key words: Education — Laparoscopy — Trainers — Virtual reality

It is well recognized that laparoscopic surgery requires a different set of skills than open surgery [1, 2, 5, 6, 9, 14, 21, 24, 26, 28]. This set of skills is helpful in overcoming the initial challenges of laparoscopic surgery, including lack of depth perception, translation of three-dimensional (3D) factors into a 2D environment, altered tactile sensation, limited degrees of freedom, long instrumentation, fulcrum effect, and different eye–hand coordination. Training in an inanimate laboratory is recommended and helpful for beginning laparoscopists [1, 3, 9, 14, 15, 19, 21, 22, 25, 27, 28]. The best method of training, however, has not yet been well established. The two basic types of training devices are virtual reality trainers and inanimate box trainers. These are both well established trainers that aid in the training of basic laparoscopic skills [7, 10, 11, 13, 14, 17, 28].

With the limited resources of most training programs, surgical educators need data to help determine the type of trainers to which resources should be dedicated. Previous investigations comparing virtual reality trainers with inanimate box trainers demonstrate conflicting results [8, 20, 29]. One study suggests that virtual reality training is better for laparoscopic skill acquisition than inanimate box training [8]. Unfortunately, the study participants were lower-level residents whose previous operative experience (both actual and observational) may not have been similar. In addition, only 19 residents had their operative metrics evaluated. No control group was included in this study.

Another investigation involved medical students. However, the study involved only 24 study students [20] and had no control group. The findings show that both the virtual reality training group and the inanimate box training group performed better than the control group after training. No consistent differences between the virtual reality training group and the box training group were noted.

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Table 1. Training tasks for virtual reality

1. Acquire and place
2. Transfer and place
3. Tranversal
4. Withdraw and insert
5. Diathermy
6. Manipulate and diathermy

Table 2. Training tasks for box trainer

Skill 1D	Placing pegs on a peg board with the dominant hand
Skill 1N	Placing pegs on a peg board with the nondominant hand
Skill 2D	Transferring pegs from one hand to another and then to the peg board, starting first with the dominant hand
Skill 2N	Transferring pegs from one hand to another and then to the peg board, starting first with the nondominant hand
Skill 3	Placing a pipe cleaner through a tube
Skill 4	Placing a probe through three different colored rings
Skill 5	Progressing from one end of the rope to the other

A more recent study involving 46 preclinical students and a control group demonstrated that virtual reality training was a better training method than box training [29]. None of these investigations compared the combination of both trainers with a single trainer alone.

We undertook the current investigation to test the hypothesis that the combination of virtual reality training and inanimate box training leads to better basic laparoscopic skill acquisition than single-device training or no training.

Table 3. Objective and subjective scoring of the laparoscopic tasks during the pre- and posttest

- Task 1. Placing a piece of bowel in retrieval bag
  - Objective scores
    - Time
    - Errors of dropped bowel or perforated bowel
  - Subjective scores (1–100)
    - Use of both hands
    - Tissue handling
    - Overall
- Task 2. Performing a liver biopsy
  - Objective scores
    - Time
    - Errors of bowel injury or dropping tape
  - Subjective scores (1–100)
    - Use of both hands
    - Tissue handling
    - Biopsy-site hemostasis
    - Overall
- Task 3. Placing a stapler on the bowel
  - Objective scores
    - Time
    - Errors of incorrect placement, bowel injury, or inclusion of other tissue in stapler
  - Subjective scores (1–100)
    - Use of both hands
    - Tissue handling
    - Overall
- Task 4. "Running" the bowel
  - Objective scores
    - Time
    - Errors of bowel injury or dropping tape
  - Subjective scores (1–100)
    - Use of both hands
    - Tissue handling
    - Overall

Materials and methods

Only preclinical medical students were enrolled in this study. An institutional review board exemption was obtained from the institution for this study. We used two training devices: the Minimally Invasive Surgery Trainer—Virtual Reality (MIST-VR; Medical Education Technologies, Inc., Sarasota, FL, USA) and the Laparoscopic Training Simulator (LTS 2000; Realsim Systems, LLC, Albuquerque, NM, USA). Both of these trainers have been shown to train laparoscopic skills [7, 10, 28].

The MIST-VR device consisted of all the computer, software, and handles received from the manufacturer. For the LTS 2000, we used disposable laparoscopic graspers and dissectors. In addition, a laparoscope, light source, and monitor were required.

The trainees were randomized into four groups: group A (MIST-VR [VR]), group B (LTS 2000 [BT]), group C (both MIST-VR and LTS 2000 [both]), and group D (no training [control]). For the randomization, four cards marked A, B, C, and D, respectively, were placed into a brown bag. A card was picked for each student, and he or she was placed in the group indicated on the card. The card was replaced in the bag, and the procedure was continued until all the students were assigned a group.

Group A was designated MIST-VR, and so forth, before randomization. Randomization occurred before the training session. No attempt was made to match the students for gender, age, or any other characteristic. All the groups except the control group trained for the same total time. Each student underwent ten 20-min sessions (i.e., a total of 200 min per student). The students who trained on both trainers spent 10 min on the MIST-VR and then 10 min on the LTS 2000 in each session. The tasks practiced on the MIST-VR (module 1) and the LTS 2000 are displayed in Tables 1 and 2. Formal instruction was given to all the students before the training sessions. The instruction included video clips of an actual patient video as well as a video of the tasks to be tested.

Before and after the training, all the students were tested in a porcine laboratory. The tasks used were designed to represent portions of commonly performed laparoscopic procedures [12]. These four separate tasks as well as the objective and subjective scoring are demonstrated in Table 3. The students were given a taped demonstration of each task a week before undergoing the test. Each task was timed, and errors were assessed. For all the students, subjective scores were given by one examiner for each task. The examiner, although present during the test, was blinded to the group represented by each student. An overall subjective score of 100 meant that the student could easily perform the task with no assistance at all, whereas 90 indicated that the student could perform the task with minimal assistance, 70 indicated that the student could perform the task but with great assistance, and 0 meant that the student could not complete the task.

The tissue-handling scores were graded from 100 (appropriate handling of tissue with no concern for injury), to 90 (appropriate handling of tissue with minimal concern for injury rarely), to 80 (appropriate handling of tissue with some concern for injury rarely), to 70 (appropriate handling of tissue with some concern for injury sometimes), to 50 (appropriate handling of tissue with major concern for injury sometimes), to 0 (appropriate handling of tissue with major concern for injury at all times).

The subjective scores for the use of both hands were graded from 100 (used both hands effectively always), to 90 (used both hands effectively most of the times), to 70 (used both hands effectively sometimes), to 50 (used both hands effectively rarely), to 0 (used both hands effectively never). Nonparametric (Kruskal-Wallis) tests with post hoc analysis (Dunn multiple comparison posttest), Wilcoxon matched pairs test, and the chi-square test were used for statistical analysis as appropriate (GraphPad InStat Version 3.05, San Diego, CA, USA).

Table 4. Mean times in the posttraining session[a]

Group	n	Task 1	Task 2	Task 3	Task 4
VR	17	26.1 ± 11.4 s	108.2 ± 49.5 s	48.9 ± 25.2 s	106.3 ± 37.7 s
Box training	14	19.9 ± 10.6 s	87.4 ± 40.5 s	52.0 ± 32.5 s	105.9 ± 46.4 s
Both	18	20.5 ± 9.1 s	69.4 ± 30.5 s	45.1 ± 17.2 s	89.9 ± 35.0 s
Control condition	16	27.9 ± 11.4 s	158 ± 152.0 s	58.6 ± 52.7 s	204.5 ± 176.1 s
p Value	For all groups	< 0.003	< 0.02	NS	< 0.01
Post hoc p values		NS (all)	NS for VR vs BT, both, control; NS for BT vs both, control; < 0.05 for both vs control	NA	NS for VR vs BT, both, control; < 0.05 for BT vs both, control; < 0.01 for both vs control

VR, virtual reality training; NS, not significant; BT, box training

[a] Data presented as mean ± standard deviation

Table 5. Subjective scores for task 4[a]

Group	VR (range)	BT (range)	Both (range)	Control (range)
Tissue Handling[b]	79.1 (45–95)	82.5 (65–95)	84.2 (65–100)	62.8 (10–90)
Overall[c]	81.8 (45–95)	84.5 (65–9	84.8 (65–98)	66.3 (10–90)

VR, virtual reality training; BT, box task training

[a] Data presented as mean (range)

[b] $p < 0.005$ for both vs control

[c] $p < 0.03$ for all groups

Results

This study involved 65 students. All students were either first- or second-year students who had no prior operative or laparoscopic experience. Table 4 depicts the number of students in each group. The mean age for each group was as follows: group A (24 ± 2 years), group B (25 ± 3 years), group C (25 ± 2 years), and group D (24 ± 2 years). There was no statistically significant between-group difference in mean age. Gender distribution did not differ significantly between the groups: group A (males 47%; females 53%), group B (males 38%, females 63%), group C (males 50%, females 50%), and group D (males 64%, females 36%). There were no statistically significant differences among any of the pretraining scores (times, errors, or subjective scores; $p > 0.05$).

The posttraining times are shown in Table 4. All the tasks except task 3 showed a statistically significant difference in times between the groups. Further post hoc analysis showed statistically significant differences between the students who trained with both trainers and the control group for all the tasks except tasks 1 and 3 ($p < 0.05$). The posttraining times were shorter for the students who trained with both trainers and those who trained with either virtual reality or box training alone for tasks 2 and 4.

The subjective scores demonstrated no differences except those for task 4 in both tissue handling ($p < 0.005$) and overall skill ($p < 0.03$; Table 5). The errors were similar for all the tasks between all the groups in the posttraining session (Table 6). Because our error rates were low, it was not surprising that no differences were seen between any of the training groups.

Table 6. Total mean errors per trainee for each task

Group	VR	BT	Both	Control
Task 1	0.0	0.0	0.0	0.2
Task 2	0.4	0.4	0.5	0.4
Task 3	0.6	0.4	0.7	0.8
Task 4	0.5	0.4	0.2	1.3

VR, virtual reality training; BT, box training

Discussion

Our data reinforce the known fact that laparoscopic trainers do improve basic laparoscopic skills. The combination of both box trainers and virtual reality trainers seems to result in the best basic laparoscopic skill acquisition. Ideally, a complete laparoscopic inanimate training laboratory should include both box trainers and virtual reality trainers.

Both trainers have pros and cons. Table 7 reviews the advantages and disadvantages of both inanimate box trainers and virtual reality trainers. Although other reports compare various devices for the training of laparoscopic skills [8, 20, 29], the current study is unique in several ways. First, our study population consisted of true novices. They were medical students who had no prior laparoscopic or surgical experience. In addition, they were preclinical medical students, and thus did not even have the opportunity to view laparoscopic surgery. Other studies have used "novice surgeons" or residents. One disadvantage with using "novice surgeons" or residents is that it is hard to standardize their true prior experience. On the other hand, this may be seen as weakness of our study because technical skills practice should ideally follow adequate knowledge acquisition.

Table 7. Advantages and disadvantages of laparoscopic skill trainers

Virtual reality trainer	Inanimate box trainer
Relatively Expensive	Relatively inexpensive
Self-contained module	Requires more instruction
Automated recording of data	Manual recording of data
Data easier to collect	Data harder to collect
Data on time, error, and economy of movement available	Data on time and error only
Easier to train and record individual hand performance [14]	Difficult to train and record individual hand performance [14]
Sophisticated metrics	Metrics not well established/difficult to obtain
Provides instant objective and validated metrics	Provides limited objective metrics
Educates hand–eye–foot coordination	Educates hand–eye coordination only
No haptic feedback	Haptic feedback
Limited handle design	May use any equipment handle
Requires less manpower	Requires more manpower
Tasks dependent on software	Unlimited tasks
Less interesting/realistic [16]	More interesting/realistic [16]

Second, our study used a control group. Occasionally, students, especially novices, will learn by just a simple pretest. The current study design took that into consideration by having a control group. More importantly, the effects of a group being trained with a combination of a virtual reality trainer and an inanimate box trainer have not been previously explored. Our belief is that, ideally, any basic laparoscopic skills training facility should have a combination of these devices [14, 16]. The data from the current study support this notion.

When subjecting our data to a post hoc analysis, we found that only the combination of the two trainers showed any statistically significant difference in relation to the control group. However, it is easy to note there were differences between either the virtual reality training group or the inanimate box training group and the control group. Although our sample size was relatively large, to determine differences between all four groups, our sample size or measured effect needed to be even larger. In addition, only task 4 ("running the bowel") demonstrated significant differences in subjective scores. We believe this is because task 4 was one of the longer tasks, allowing the evaluator more opportunity to grade the participants. Unfortunately, it also may be true that our subjective grading may not have been robust enough to discriminate subtle differences between the subjective scores for the other tasks.

It is difficult to ascertain why students who used both training devices did better on their laparoscopic skill acquisition. Some students may learn better in a more high-tech learning environment (i.e., virtual reality), whereas others may learn better in a more traditional learning environment (i.e., inanimate box training). Combination therapy is certain to educate both types of students. Furthermore, training may be considered mundane or boring after a while, and two different devices may capture the attention of students longer, which would further facilitate laparoscopic skill acquisition. In fact, our previous investigation demonstrated that many participants found a box trainer more realistic and interesting than virtual reality trainers [16]. Whatever the reasons, a combination of virtual reality trainers and inanimate box trainers resulted in better laparoscopic skill acquisition.

This study had some limitations. First, our sample size could have been larger. However, the number of participants in this study was larger than in most other studies investigating laparoscopic training. With a small sample size, other confounding factors may have been involved, although our groups had similar gender and age characteristics. Furthermore, the tasks chosen for the metrics in the porcine model may resemble the tasks on one trainer rather than the other. Because neither trainer demonstrated better skill acquisition than the other, this does not seem to be the case.

Second, we did not determine the point at which novices would have sufficient skill to perform certain tasks laparoscopically. In other words, training time (not level of achievement) was used to determine when training was complete. Our training time of 200 min may or may not have been sufficient for students to be trained appropriately. Specifying the training time on these devices may not be the best method of training. Instead, a certain proficiency to be reached should determine how much trainees need to train. However, the whole purpose of our report is to compare two different training devices.

Our error level was low, which may suggest that our tasks were not sufficiently complex or that our definition of error was not subtle enough. In addition, we used a relatively simple form of metrics (time, error, and subjective scores). More sophisticated metrics exist, such as the Objective Structured Assessment of Technical Skill (OSATS) [4, 18, 23]. However, we believe that for the purposes of this study, our choice of metrics was sufficient to ascertain some differences between the training groups. Unfortunately, no standard metrics for testing surgical skill (laparoscopic or open technique) have been well developed, accepted, and validated in an animate model.

This study investigated only technical skill. True laparoscopic skill, like any surgical skill, involves judgment, knowledge, and technical skill. These are not developed with trainers alone, but also with a laparoscopic curriculum that uses trainers as the building blocks for basic technical skill. Without reinforcement of the technical skills during procedures (whether in actual patients, cadavers, or animal models), training of a technical skill does not truly serve the ultimate goal of training residents or surgeons in laparoscopic procedures. This study did not investigate true laparoscopic skills in actual patients. These would be difficult to ascertain in a test for medical students.

Our study demonstrates that the combination of virtual reality and inanimate box trainers lead to better basic laparoscopic skill acquisition. Practically, it is difficult for many training programs to provide or obtain appropriate funding and resources for both types of trainers. Ideally, however, any complete laparoscopic skill laboratory should include both types of trainers.

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