Original paper

Videosurgery

Structuralized box-trainer laparoscopic training significantly improves performance in complex virtual reality laparoscopic tasks

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Abstract

Introduction: *In the era of flowering minimally invasive surgical techniques there is a need for new methods of teaching surgery and supervision of progress in skills and expertise. Virtual and physical box-trainers seem especially fit for this purpose, and allow for improvement of proficiency required in laparoscopic surgery.*
Material and methods: *The study included 34 students who completed the authors' laparoscopic training on physical train-boxes. Progress was monitored by accomplishment of 3 exercises: moving pellets from one place to another, excising and clipping. Analysed parameters included time needed to complete the exercise and right and left hand movement tracks. Students were asked to do assigned tasks prior to, in the middle and after the training.*
Results: *The duration of the course was 28 h in total. Significant shortening of the time to perform each exercise and reduction of the left hand track were achieved. The right hand track was shortened only in exercise number 1.*
Conclusions: *Exercises in the laboratory setting should be regarded as an important element of the process of skills acquisition by a young surgeon. Virtual reality laparoscopic training seems to be a new, interesting educational tool, and at the same time allows for reliable control and assessment of progress.*

Key words: *surgical training, virtual laparoscopy, surgical curriculum, pre-graduate training, post-graduate training, box trainer, virtual trainer.*

Introduction

For decades, training in surgery was based on the famous “see one, do one, teach one” model developed by Halsteadt [1-3]. In the era of blossoming laparoscopy and innovative minimally invasive techniques (SILS, NOTES), pursuing this classical model becomes increasingly challenging. Presence in the operating room is inevitable and there is no surgical training away from it, but at the same time acquisition of basic surgical skills outside the operating theatre also seems necessary. Such training shortens the learning curve, gives insight into laparoscopic procedures specificity and reduces the number of potential complications [4]. Consequently, such training, although relatively expensive, becomes economically effective in the long-term [5-7]. It can be achieved with physical and virtual trainers [8, 9]. The latter allow for repeatable simulation of complete surgical procedures and very precise measurement of parameters such as the time, length of tool track, number of errors, tissue tension, virtual blood loss, etc. [2, 10], which makes them ideal tools for monitoring the effectiveness of learning.

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Aim

The aim of our study was to evaluate the effectiveness of laparoscopic surgery training techniques using box-trainers and the virtual LapSim VR 3000 simulator.

Material and methods

Population

The study involved 34 students of the GUMed medical faculty. The programme included 28 h of box trainer exercise classes (each 45 min long) in 2-people groups. Activities were supervised, instructed and guided by two coaches: a general surgery specialist with extensive experience in minimally invasive surgery and a resident capable of performing basic laparoscopic procedures. Classes were structured in the form of five exercises practised according to the set timetable. After briefing and instruction, students repeated the new exercise 3 times under the supervision of the coach. Time to complete each exercise was recorded. In the subsequent training sessions new exercises were introduced and all previously trained exercises were repeated once.

The authors used two Karl Storz physical trainers consisting of a standard container, trocars, tools (needle holders, dissectors, graspers, laparoscopic scissors), 30-degree 10 mm camera, light source, and 17'' LCD monitor. Depending on the exercise, a cup, some buttons and suture could be found inside the container (Figure 1).

- Exercise 1 – to collect ten buttons of various shape (always the same set of buttons) from the bottom of the box into a cup (Figure 2).
- Exercise 2 – as in exercise 1, collection of 5 buttons but with reverse optics.
- Exercise 3 – to thread a button (held with a dissector) with a surgical needle held in a needle-holder; 'forehand' needle rotation (i.e. clockwise) repeated five times (Figure 3).
- Exercise 4 – as in the previous exercise but with opposite needle rotation – "backhand"; three repetitions.
- Exercise 5 – with two laparoscopic needle holders a participant is supposed to tie a tight surgical knot consisting of three individual units (Figure 4).

Participating students had no prior contact with practical aspects of laparoscopic techniques. In the initial survey, when the participants self-assessed their ability to use laparoscopic tools with the VAS scale in the range 0-10, their average baseline laparoscopic skills were 1.14 ±1.19.

Study design

Participants training in the laparoscopic technique were tested three times with a virtual simulator (a series of three exercises at the 1st, 4th and 7th meeting – measurement results were described as

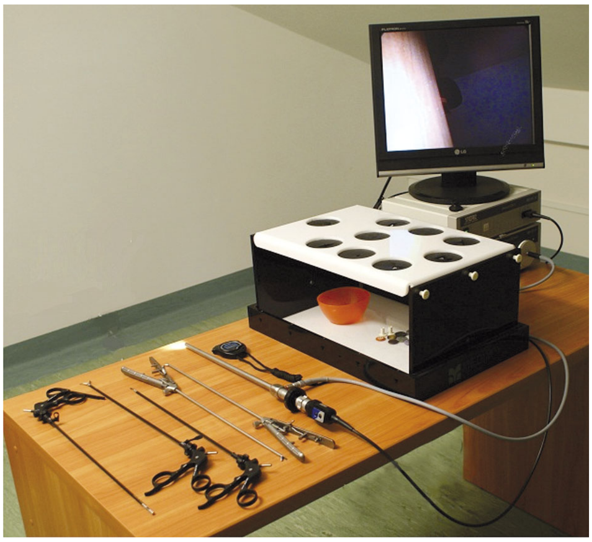


Figure 1. General view of a Carl-Storz physical trainer

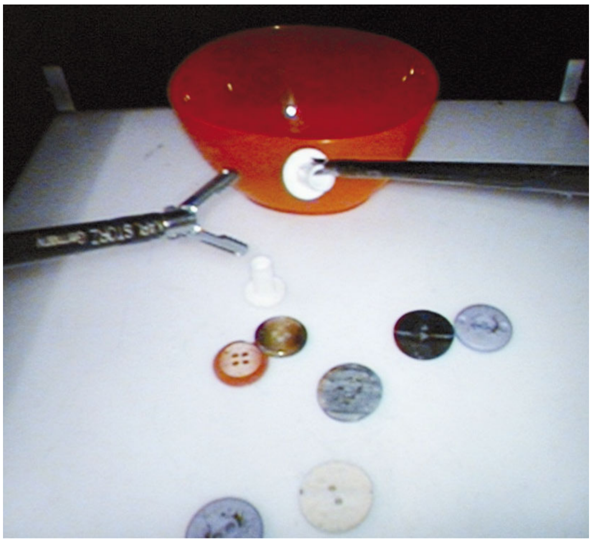


Figure 2. Exercise 1 – monitor view from the physical trainer

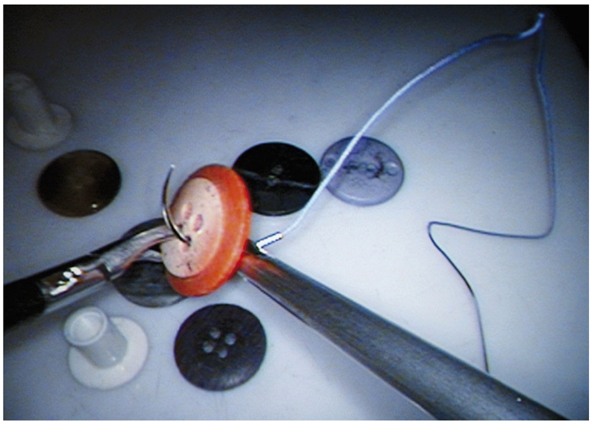


Figure 3. Exercise 3 – view from the physical trainer

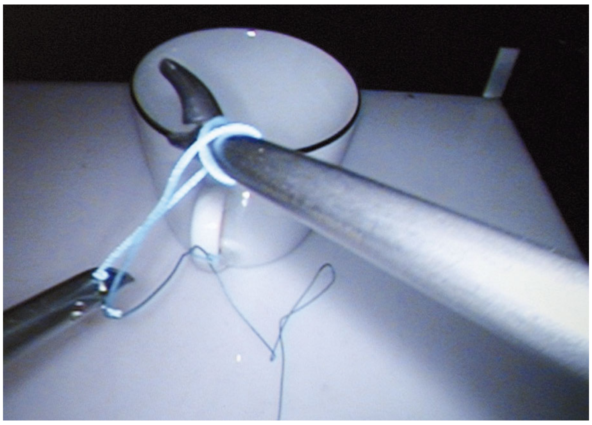


Figure 4. Exercise 5 – view from the physical trainer

1, 4 or 7, respectively). In the meantime, students trained on physical box-trainers according to the learning schedule outlined above.

- Exercise 1 on a virtual trainer: "Peg transfer" – involves transfer of capsules and placing them on a stand (Figure 5).
- Exercise 2 – "Virtual cutting" – cutting a circle of a fabric stretched in a virtual space while adhering to predetermined precision of the movement (Figure 6).
- Exercise 3: "Virtual clipping" – the participant is supposed to clip a blood vessel and then cut precisely between the clips (Figure 7).

Three parameters were selected for evaluation of the training progress: task execution time (in seconds), the path of the trainee's right hand (in metres) and the left hand track (in metres).

Statistical analysis

The collected data were subjected to analysis of variance (ANOVA) and *post-hoc* Scheffe test with Statistica 9.1 PL. Non-parametric data were tested with the χ^2 test. Values of p below 0.05 was considered statistically significant.

Results

Average attendance in the laparoscopic group was 4.88 ±1.21 training sessions which resulted in a mean of 14 h 38 min ±3 h 38 min of training. Of 36 study participants 14 were women (40%), mean age was 23.6 ±2.85 years and the vast majority were right-handed (94%).

When analysing the results achieved by the students training in the laparoscopic technique, statisti-

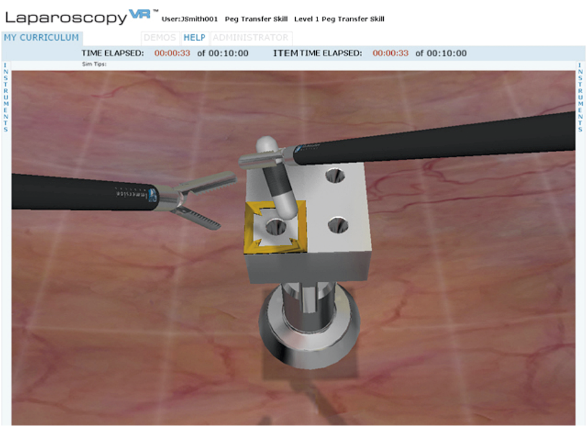


Figure 5. Exercise 1 – view from the virtual trainer

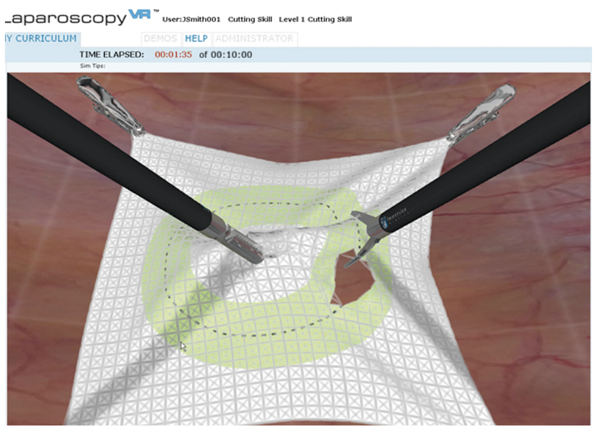


Figure 6. Exercise 2 – view from the virtual trainer

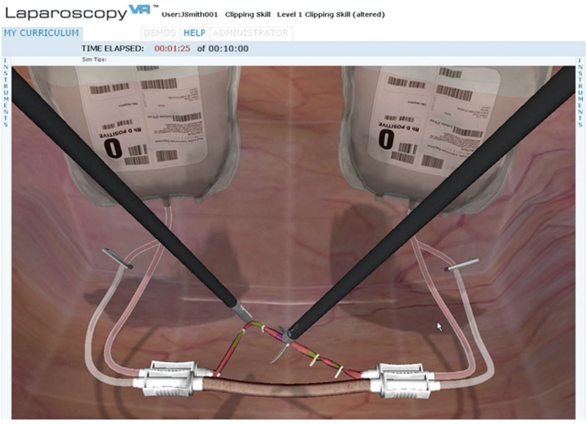


Figure 7. Exercise 3 – view from the virtual trainer

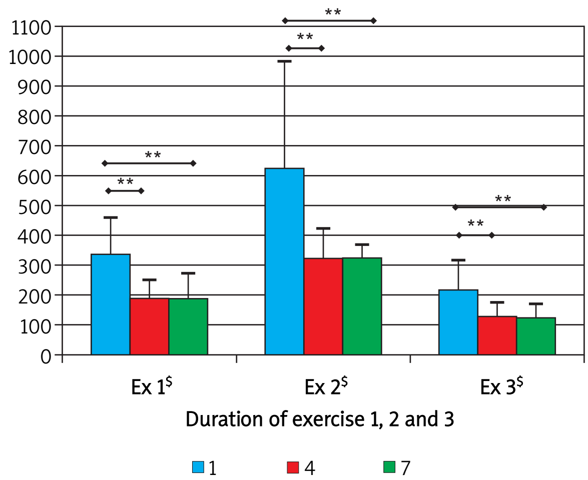
cally significant reduction of the task completion time for all the exercises was found (Figure 8). The motion path of the tool held in the left hand was also shortened significantly (Figure 9). The track of the right-hand tool was reduced only in exercise 1 (Figure 10). Table I shows the progress made by students during the course of exercises.

Discussion

This study, for the first time in Polish literature, presents a formal didactic programme of training in laparoscopic skills which includes testing of the effectiveness of the adopted curriculum using a virtual simulator, one of a few in our country. We have proved that the training we implemented results in a significant improvement of skills of operating with laparoscopic instruments. The trainees progressed by 40-70% of the baseline in the majority of the parameters. Similar results were noted by other authors. Stefanidis *et al*. achieved 17-59% improvement in residents' laparoscopic skills with a training programme based on virtual training [11].

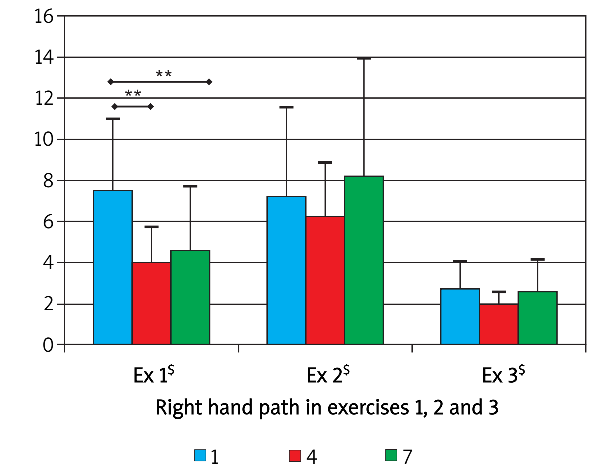
Laparoscopic training in specially prepared centres has become an integral part of surgical training of residents in Western countries [5, 12, 13]. Such training improves safety of laparoscopic procedures [4, 12, 13] performed by young surgeons. Training on a virtual or physical box-trainer significantly amends duration and economy as well as movement precision in basic laparoscopic skills, and directly corresponds with the results achieved in a real operating theatre [4, 14-18]. Trainees quickly reach the expertise level recognized by experts as satisfactory [19, 20] and the learning curve tends to plateau [19]. A similar trend was observed in students in our survey.

Negligible progress in right hand movement was most likely associated with the great preponderance



$In-group ANOVA p < 0.001
***post-hoc Scheffe test p < 0.05*

Figure 8. Average duration of exercise 1, 2 and 3 (Ex 1, 2, 3) on a virtual trainer (in seconds, ± SD). The bars are marked respectively as 1, 4, 7 – for the measurement made on the first, fourth and seventh (final) meeting



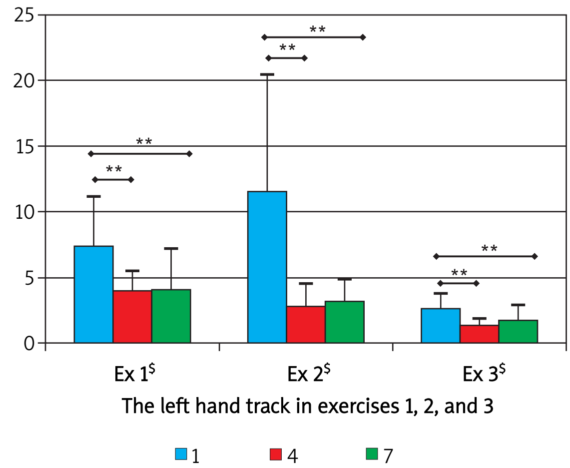
$In-group ANOVA p < 0.001
***post-hoc Scheffe test p < 0.05*

Figure 9. Average length of motion path of the right hand during the execution of exercises 1, 2 and 3 (ex 1,2,3) on a virtual trainer (in metres, ± SD). The bars are marked respectively as 1, 4, 7 – for the measurement made on the first, fourth and seventh (final) meeting

of the right-handed in the study group. Only exercise 1 (“PegTransfer”), involving both hands equally, showed progress with training. Hence, the right hand was not dominant in half of the exercise, leading to less control during the first execution of the task. Other exercises, with key movements performed with the right hand, and therefore without its non-dominant participation, have not shown any progress in the right hand track. Its performance was satisfactory already in the first pass despite the suboptimal time of exercising. In these two exercises, progress was noted in exercise execution time and non-dominant hand performance. Similar results were also reported by other authors, who observed reduction of exercise duration, the number of repetitions necessary to obtain an acceptable result and shortening of the non-dominant but not the dominant hand path length with training [21].

For several years, virtual trainers with active biofeedback and high quality graphics (as used in the simulation study) were considered a reliable and objective educational and assessment tool [10]. Recently, more and more studies analysing the impact of various forms of training on getting faster and more durable results have been published. Snyder *et al.* analysed the influence of an expert on effects of simulator-set goals-targeted training. In a group of 32 trainees they demonstrated that training without an expert does not result in faster achievement of the desired outcome [22]. Hence, training cost reduction is possible.

Naturally, a stimulator-designated target-based training strategy cannot be achieved with the box-trainer, which nevertheless gives comparable training effectiveness [23]. Similarly, while trying to reduce training cost, application of virtual trainers without a haptic option (sensation of touch) was found to be equally effective [21]. Other activities in this area were presented by Hull *et al.* To increase the reality of an exercise in a box-trainer, they wallpapered the interior of the box with photographs of the abdominal cavity content, and painted the box-trainer outside in the colour of flesh. Surgeons participating in the study admitted that it increased the sensation of reality of exercises [24]. A goal-based training strategy, whether set by the simulator or by the tutor, seems to be particularly effective and motivating, both in the laboratory and in clinical settings [11, 25]. This form of pre-and post-graduate training seems to be most recommendable, yet it requires fundamental changes in the conception of teaching surgery in Poland.



$In-group ANOVA p < 0.001
**post-hoc Scheffe test p < 0.05

Figure 10. Average length of the left hand motion path during exercises 1, 2 and 3 on the virtual trainer (in metres ± SD). The bars are marked respectively as 1, 4, 7 – for the measurement made on the first, fourth and seventh (final) meeting

Table I. Progress made in studied performance elements between the first and final exercise repetition

	Ex 1	Ex 2	Ex 3
Exercise execution time	44%	48%	42%
Right hand track	39%	–14%	3%
Left hand track	44%	72%	32%

Conclusions

We wish to draw attention to the importance of laboratory training as an essential element in modern surgical education. The presented tuition scheme facilitates fairly supervised exercises and continuous monitoring of progress.

We believe that this topic, poorly represented in Polish literature yet very central for the development of surgery, deserves further studies.

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