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ORIGINAL ARTICLE

Home virtual reality simulation training: the effect on trainee ability and confidence with laparoscopic surgery

Jonathan Barnes,[a,*] Jessica Burns,[a] Craig Nesbitt,[a,b] Helen Hawkins[a] and Alan Horgan[a,b]

[a]*Department of Surgery, Freeman Hospital, Newcastle-upon-Tyne, UK;* [b]*Newcastle Surgical Training Centre, Freeman Hospital, Newcastle-upon-Tyne, UK*

**Corresponding author at: Freeman Hospital, Freeman Road, Newcastle Upon Tyne, NE7 7DN, UK. Email: jonathan.barnes77@gmail.com*

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Abstract

Introduction: Virtual reality simulation (VRS) attempts to replicate surgical scenarios and offers performance feedback, making it a valuable training tool. However, VRS use is limited by costs, availability and accessibility. Cheaper portable units may therefore be invaluable. Previous studies have shown face validity for such modalities of training although no study has assessed whether home simulation training actually improves surgical performance. **Methods**: Twenty-one surgical trainees were split into practice ($n = 10$) and control groups ($n = 11$). Both groups performed two simulated laparoscopic cholecystectomies 1 week apart. Data on technical ability (operation time, time taken for gallbladder removal, cautery efficiency and total instrument movements) and safety (cautery safety, complications and perforations) were recorded. Between cholecystectomies, the practice group were given a portable VRS unit to use at home. The practice group were assessed on their procedural confidence before and after training. **Results**: The practice group showed significant improvements in operation time (19.02 to 14.96 min, $P < 0.05$) and cautery efficiency (59.8% to 65.1%, $P < 0.05$) between procedures, whereas the control group showed no changes. Further improvements in time taken for gallbladder removal (16.5 to 11.3 min, $P < 0.05$) and instrument movements (979 to 710, $P < 0.05$) were seen in the more experienced trainees. The practice group showed significantly increased procedural confidence, assessed using a visual analogue scale, after training (46.6% to 67.6%, $P < 0.01$). **Discussion**: This study shows that home simulation training significantly improves trainees' confidence and laparoscopic skills. Further studies are needed to develop understanding of how best to utilize this potentially valuable surgical training tool.

Keywords: *simulation; home simulation; portable simulator; training; education*

Introduction

Surgical practice and training has changed dramatically in recent years and continues to evolve. Tighter working time regulations and increasingly rigid training schemes are affecting trainees' opportunities to spend time in the operating theatre.[1,2] Furthermore, the constant development of more technically demanding techniques and increasing patient expectations[3] have led to current surgical trainees having fewer opportunities to gain practical surgical experience than previous generations.[1,4] The traditional master–apprenticeship model of "see one, do one, teach one" is becoming outdated and inappropriate.[2,5]

One increasingly popular educational tool is virtual reality simulation (VRS).[6–8] Commonplace in the aviation, military, nuclear and maritime industries,[9] these systems are playing an increasing role in surgical training. VRS has been shown to effectively replicate surgical scenarios,[4] allowing trainees to practice and develop skills without having to expose patients to non-expert care. In addition to accurate reproduction of surgical procedures, VRS systems can simulate complications[8] and can also be used objectively to record and provide feedback on trainees' operative performance.[1,7] VRS has been shown to be particularly useful for laparoscopic surgical training due to its two-dimensional and technically demanding nature.[8,9]

A major barrier to providing VRS training is that the simulators can be prohibitively expensive to set up and run[10,11] and are often static, immobile units that cannot be used outside the training centre and outside normal working hours. However, there is emerging evidence that more basic portable VRS units that trainees can use at home may be equally effective in skillset acquisition and development[11] compared with standard units. If verified, these units would allow VRS training to become more widely used. Furthermore, portable units allow trainees to practice outside the confines of working hours, allowing them to practice in a more distributed manner and at their own pace. This allows the user to train to a criterion-based, rather than time-based, syllabus, which has been shown to increase skill set acquisition and development.[10,12]

Simulation training has also been shown to improve confidence.[13] Increased confidence, in turn, is associated with increased engagement in real-life training opportunities[14,15] and is correlated with improved knowledge[16] and clinical performance.[13,17]

Although becoming more popular, no study has assessed whether training with portable VRS units leads to actual tangible improvements in operative performance, or indeed improves trainees' confidence at performing laparoscopic procedures.

This study aimed to assess the feasibility and acceptability of a home VRS training programme. We also aimed to establish if unsupervised home VRS training would lead to any objective improvements in operative laparoscopic performance or confidence in laparoscopic surgery in a group of junior surgical trainees.

Methods

Twenty-one surgical trainees (core training year one) in a large university teaching hospital were enrolled. The study period lasted 6 months. The first 10 trainees were recruited to the practice group and the next 11 to a control group. Background information on how many laparoscopic cholecystectomies trainees had assisted with and performed was collected. Before training commenced, trainees were asked to complete a supervised laparoscopic cholecystectomy using a high-fidelity, haptic feedback, virtual reality training unit. The model used was the Lap Mentor (Lap Mentor, Simbionix, Cleveland), a VRS training tool with proven construct validity that has been used in similar studies and has content validity as a tool to measure trainee performance.[12,18–20]

Objective performance data were collected in the following areas;

- Technical ability: operation time, time taken to remove the gall bladder, efficiency of cautery (calculated from total cautery time and cautery time without contact) and total instrument movements.
- Safety: safety of cautery (calculated from total cautery time and amount of cautery <5 mm from the duct or <15 mm from the clip), numbers of serious complications and numbers of perforations.

The practice group were given a portable VRS unit (SimEndo, Rotterdam) to practice with at home (Fig. 1). They were orientated as to how to use the machine then allowed to take it away for 1 week with a syllabus of tasks to undertake. The syllabus contained tasks to complete, ranging from beginner to expert level. They were based around instrument movement and manipulation and depth and visual perception (Fig. 2). Trainees were asked to keep a practice diary. Trainees were permitted to use their VRS units as much or as little as they wished, which allowed us to establish the practicality and acceptability of home VRS training.

Both groups (practice and control) were then asked to perform the laparoscopic cholecystectomy a second time (using the Simbionix simulator), 1 week after the first to reassess their technical performance, based on the objective feedback data generated by the simulator.

Trainees in the practice group were also assessed on their confidence and self-reported ability. After completing the simulated laparoscopic cholecystectomy for the first time, they were given a questionnaire which, using visual analogue scales (0–100), measured their self-reported abilities with laparoscopic equipment. They were questioned regarding their ability with instruments, camera ability, tissue handling, manual dexterity, visuospatial awareness, depth awareness and overall confidence and self-perceived ability. They were then asked to assess their abilities again, with the same form, having completed a week's practice with the portable VRS unit. The methods are summarized in Fig. 3.

Figure 1 SimEndo controls, which can be connected to any computer and used to run a VRS surgical training programme.

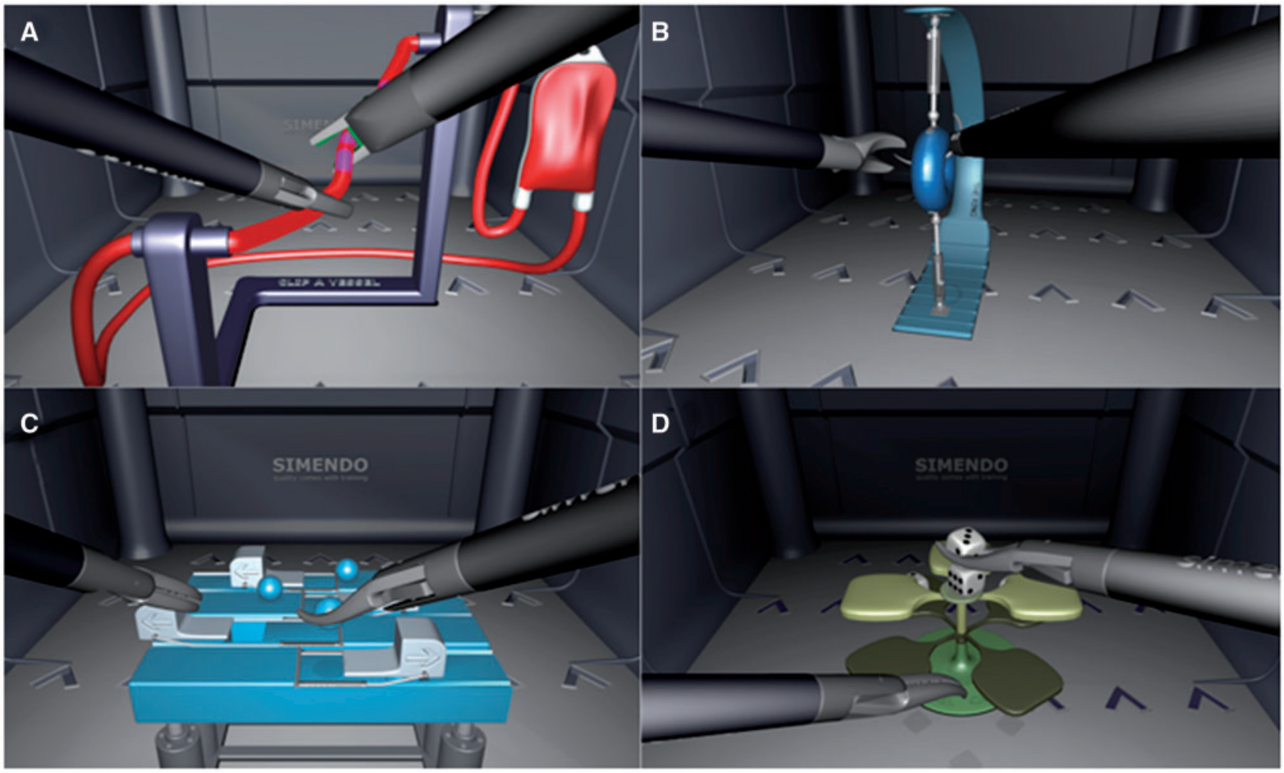

Figure 2 Examples of the tasks that trainees were asked to complete as part of the portable VRS training syllabus. A, clipping a vessel; B, passing a needle through a ring; C, moving sliders/placing balls; D, placing dice on a carousel.

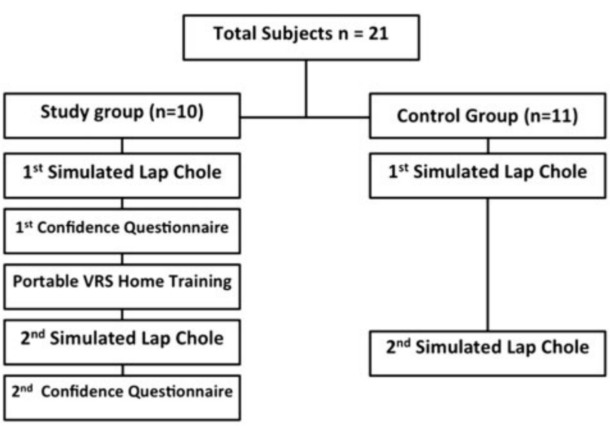

Figure 3 Methodology flow chart.

Intra-group results were analysed using a paired Student t-test and an unpaired Student t-test was used to analyse intergroup variation.

During the study period, both the portable VRS units and standard high-fidelity laparoscopic VRS models were available for all surgical trainees in the region to use during office hours (08:00–17:00 h) at the regional simulation training centre (Northern Surgical Training Centre).

Results

Trainees spent a mean of 196 min (SD = 30.4 min) over 3.6 sessions (SD = 1.96) practicing with the portable VRS unit (Table 1). Except during compulsory sessions, no surgical trainee accessed either the standard high-fidelity laparoscopic VRS unit or any of the simple box trainers housed in our regional simulation training centre during the study period.

Operative performance

No significant differences in performance were seen between the control and practice group after the first simulated laparoscopic cholecystectomy.

The control group showed no significant changes in any measure of technical ability or safety when performing a second laparoscopic cholecystectomy 1 week after the first.

In the practice group, significant improvements were seen in total operation time (19.02 to 14.96 min, $P = 0.038$) and cautery efficiency (59.8% to 65.1%, $P = 0.047$). No other changes reached statistical significance (Fig. 4). Time to extract the gall bladder (17.00 to 14.45 min) showed a strong trend towards significance ($P = 0.062$) as did the number of perforations made in the gallbladder during

Table 1 Time and sessions spent practicing by trainees in the practice group

Candidate no.	Training total (min)	Sessions	Average time per session (min)
S1	270	3	90.0
S2	180	3	60.0
S3	150	2	75.0
S4	150	3	50.0
S5	330	4	82.5
S6	170	3	56.7
S7	180	3	60.0
S8	130	1	130.0
S9	240	7	34.3
S10	160	7	22.9
Average	196	3.6	66.1

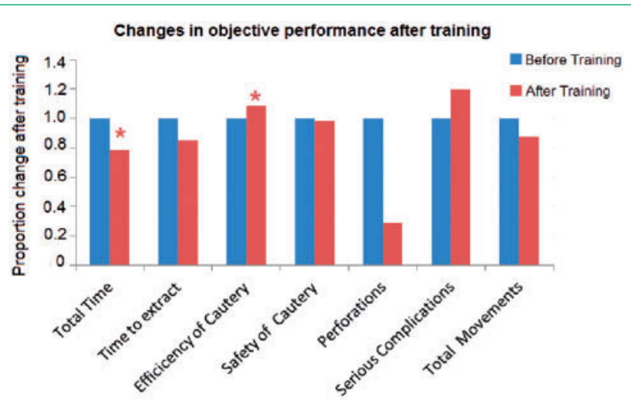

Figure 4 Changes in objective data before and after portable VRS training (*$P < 0.05$) in the practice group.

extraction (5.6 to 1.6, $P = 0.060$), although neither reached statistical significance.

Intergroup comparison for the second laparoscopic cholecystectomy again revealed no significant differences in objective performance data.

Trainees were divided into subgroups based on their previous experience (assisting and performing laparoscopic cholecystectomies) and the amount of time they spent practicing.

The high-experience group included those who had assisted with more than 25 laparoscopic cholecystectomies ($n = 5$); the low-experience group included those who had assisted with 25 or less ($n = 5$). In the low-experience group, no significant changes were seen in any domain after training. However, in the high-experience group, participants showed significant improvements after training in total operation time (average 17.2 min before training decreasing to 11.7 min after, $P = 0.02$), time to remove gallbladder (16.5 min decreasing to 11.3 min, $P = 0.02$), total instrument movements (decreasing from 979 to 710, $P = 0.03$) and cautery efficiency (increasing from 55% to 66%, $P = 0.03$) (Fig. 5).

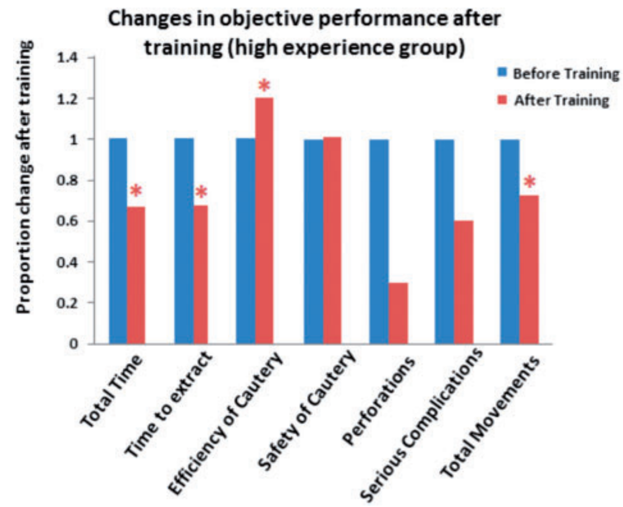

Figure 5 Changes in operative performance data before and after portable VRS training in the high-experience group (*$P < 0.05$).

The high-practice group included those who had spent over 3 h practicing with the portable VRS unit ($n = 5$). The low-practice group included those who had spent less than 3 h practicing ($n = 5$). No significant differences in performance were seen after training in either group.

Operative confidence

Trainee self-reported ability improved significantly after practicing with the portable VRS unit in every domain except camera use (Fig. 6).

Overall, trainees rated their confidence with laparoscopic instruments at 46.4 before and 67.6 afterwards, a 45.7% relative increase ($P = 0.006$) (Fig. 7).

Discussion

VRS has become an established tool in surgical training, and changes to working patterns and the role of the junior surgeon in the operating theatre suggest that it may become increasingly valuable. VRS does, however, have drawbacks. Most notably, training units can be prohibitively

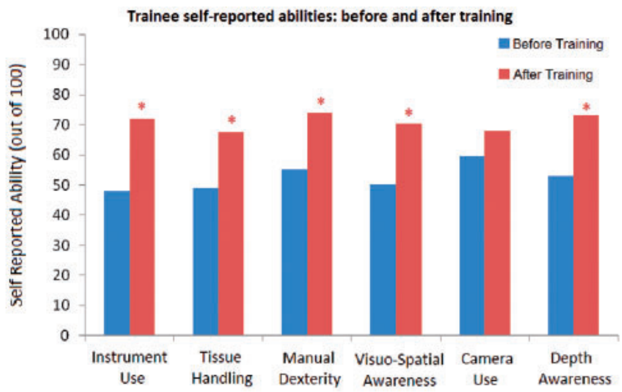

Figure 6 Changes in trainee confidence in different areas related to laparoscopic surgery before and after portable VRS training (*$P < 0.05$).

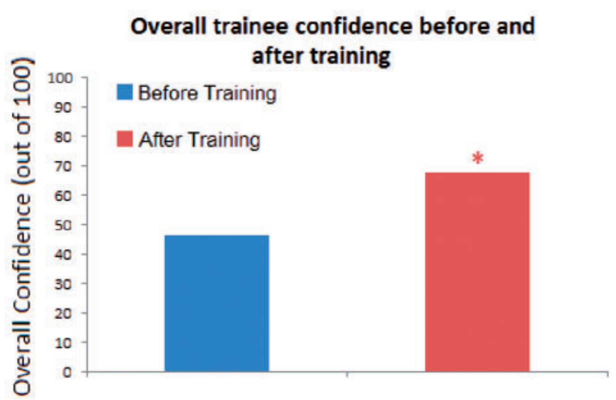

Figure 7 Changes in trainee overall confidence with laparoscopic equipment before and after portable VRS training (*$P < 0.05$).

expensive to set up and maintain and, due to their expensive and immobile nature, simulators need to be kept in hospitals and universities and are often only available to trainees during working hours, which severely limits the busy surgical trainee's opportunity to use them and may lead to "non-optimal training schedules".[10]

Portable simulators, which are much cheaper than standard units and can be taken off-site and used outside office hours, may help overcome some of these issues. The portable simulators used in this study cost less than 10% of the price of a standard VRS unit. Portable simulators also allow trainees to practice at their own pace, when it suits them, which facilitates them getting the most out of the simulation programme.[10] Verdaasdonk et al.[21] showed that trainees and experienced surgeons alike believe portable VRS to be a useful tool for surgical training. They also showed that repeated training with a portable VRS unit leads to progressive improvements in performance when undertaking the tasks on the simulator syllabus,[22] and training with a portable VRS unit can also improve basic surgical technique (knot tying) when then assessed in real life.[23] However, it has never been reported whether home VRS training can actually improve ability to perform a procedure (whether simulated or real) or have an impact on user confidence. It has also not previously been reported whether portable VRS units actually increase trainee uptake and engagement with VRS training.

This study shows that portable virtual reality simulators for use at home are not only acceptable to trainees, but they actually increase trainee use of VRS and their use leads to measurable improvements in their confidence in laparoscopic surgery and their intraoperative technical performance. This study used subjective data, relating to trainees self-reported ability, and objective data, measurements of surgical performance generated by the simulator, to measure performance changes.

In this study, every marker of ability with laparoscopic equipment improved after portable VRS training, with total operation time and cautery efficiency improving significantly. This was with an average of just 196 min of practice using the portable VRS unit. In the control group, no ability markers showed significant improvement. These results suggest that even a small amount of practice with a portable VRS trainer can lead to improvements in technical ability with laparoscopic equipment. This is in keeping with other similar studies using non-portable simulators.[2,4,22,23]

This study also assessed markers of safety. In the control group no improvements were seen in any of these parameters. In the practice group perforation rates decreased from a mean of 5.6 to 1.6, a result that did not reach, but had a strong trend towards, statistical significance. These results suggest that portable VRS training may also make trainees safer with laparoscopic equipment, as well as improve their technique. However, the less conclusive results suggest that to become safe with a surgical technique requires a greater amount of exposure and practice time than that required to simply become able to perform it.

Alongside the objective markers of performance, these results clearly show that practice with the portable VRS unit made trainees feel more confident in their ability with laparoscopic equipment. All of the areas assessed, except for camera use, showed significant improvements after trainees had practiced with the unit. The lack of significant improvement in camera use, coupled with the fact that it was the area in which trainees ranked their confidence most highly before training may represent the fact that it is the area that, at junior level, trainees get most experience with in their normal day to day work. Therefore, to gain improvements in confidence may require more extensive training than that required to gain improvements in the other areas assessed. The overall improvement in trainee confidence may have contributed, in part, to the improvements in operative performance seen in the objective data.

Previous simulation studies have suggested that improvements in performance are likely to be more pronounced in those with a greater level of previous surgical experience.[22] We also found that improvements in performance were much more uniform and more pronounced in the group with the higher background experience, suggesting that VRS training may be of more benefit to those who already have an understanding of laparoscopic surgery. This may be due to the fact that VRS training is more suited to skill set development rather than acquisition, which may be achieved most effectively by direct teaching from an expert.

No significant differences were seen between the high- and low-practice groups in this study. However, this was a small pilot study with the simple goal of assessing whether training with a portable VRS unit led to any improvements in trainee confidence and competence. Further work, with larger numbers, may help quantify how much training is the optimal amount and therefore how best portable VRS can be incorporated into current surgical training.

Perhaps one of the most interesting findings of this small study is that during the trial period (6 months) no surgical trainee accessed our simulation training facility to use any traditional VRS or bench-top box trainer, outside of their prescribed training sessions. The centre is open 5 days per week from 08:00 h until 17:00 h. Since the conclusion of this trial, our unit has adopted a dedicated home simulation training programme, in which surgical trainees can join a waiting list to loan out the units for a week at a time. Their popularity has been unprecedented. This suggests that simulation training is a massively underused resource, and portable VRS units may provide the solution. Further work to assess trainee uptake and training effectiveness of portable VRS compared with box simulators would be of interest.

Home VRS training enhances VRS use, improves confidence and leads to improvements in surgical performance, as demonstrated on a high-fidelity virtual reality simulator.

Despite some clear conclusions, the findings of this study should be interpreted carefully as the results are subject to a number of limitations. First, the sample size was small and participants only performed the simulated laparoscopic cholecystectomy once before and after training. This could have led to a good day/bad day phenomenon, which may have skewed results. A larger sample size, with participants performing the procedure several times, or performing several different laparoscopic procedures, may be an improvement for future studies. The use of a group of participants and a control group may, however, have partially controlled for this issue.

Second, although the participants were at the same stage of training, they were not randomized. This potential selection bias could have resulted in the practice group being made up of a keener group of trainees who may not be representative of the typical trainee.

Another limitation of this study, relating to high versus low experience, is that only data about how many laparoscopic cholecystectomies trainees had observed were recorded. It is possible that some trainees who were actually very experienced with laparoscopic equipment, but in a different operative setting, were put into the low-experience subgroup. This may have led to results that contradict the conclusion that those with more background experience benefit more from this type of training.

A potential addition in future, larger studies, would be to integrate a senior review process, alongside self-assessment data and the raw performance data generated by the simulator. Although again a subjective marker of performance, it would be useful because sometimes simple numbers (e.g. total operation time) do not give the full picture of how a trainee is performing. It would also be a useful feedback format to use if this study were to be reproduced/expanded using an actual (non-simulated) surgical procedure in which measuring objective markers may be more difficult and unethical.

Despite these limitations, this study has shown that use of portable VRS units outside the workplace is acceptable to surgical trainees and home simulation training is feasible. Home VRS training enhances trainee confidence in laparoscopic surgery and is effective in improving safety and surgical performance, albeit in a simulated setting. Further work is undoubtedly required to develop a deeper understanding of how to gain maximal benefit from their use but these early results are encouraging.

Conflict of interest

No conflicts of interest have been declared.

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