Intelligent Automation And Soft Computing, 2020
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Vol. 26, no. 1, 53–59
DOI: 10.31209/2019.100000149

Laparoscopic Training Exercises Using HTC VIVE

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ABSTRACT
Laparoscopic surgery is a relatively new field in developing countries. There is a scarcity of laparoscopically trained doctors due to a lack of training and resources available in hospitals. Training and evaluation of medical professionals to develop laparoscopic surgical skills are important and essential as it improves the success rate and reduces the risk during real surgery. The purpose of this research is to develop a series of training exercises based on virtual reality using HTC Vive headset to emulate real-world training of doctors. This virtual training not only gives the trainee doctors mastery in their profession but also decreases the chances of complications during laparoscopic surgery. After practicing on our simulator for three trials, doctors report enhancement in the following skills: time to complete a task, precision, efficiency of a task, and the recorded movements of surgical instruments using both hands. Our simulator is comparatively low cost as compared to the available simulator in the local market

KEYWORDS: HTC VIVE, Laparoscopic training, Virtual reality.

1 INTRODUCTION

WITH the invention of Laparoscopy and MIS (minimally invasive surgery), the idea of surgical simulators and virtual reality was introduced in the field of surgery. In 1987 the first laparoscopic surgery was performed by Mouret. It was a laparoscopic cholecystectomy back in 1987, which revolutionized the field of surgery. The skill set requirements of laparoscopy are very different from conventional surgery. In laparoscopy, there is no tactile feedback, a transformation from 3D to 2D world and most importantly precise hand-eye coordination is required.

The evolution of surgery came with the introduction of virtual reality and surgery simulation in the surgical field. The learning curve in MIS (minimally invasive surgery) procedures is more abrupt in comparison to the open surgery as trainees not only have to get familiarized with the new technology presented to them and also overcome certain challenges that come along with it e.g. the fulcrum effect but are also required to have an appropriate up to the mark knowledge and grip on the surgical techniques as well. Hence surgery simulation has become a vital tool in training the young doctors, giving them the freedom to practice laparoscopy and minimally invasive surgery outside the operating room. This training not only gives the young doctors a well-rounded education but also decreases the chances of complication during a surgical procedure.

Economic factors are also affecting the training of doctors. The elective waiting lists a young doctor is on before being assigned to surgery and the time pressures in a surgical room account for important factors to the operating room practice a training doctor receives. As the cost of new operative technologies is increasing rapidly and the global economy is declining, the financial limitations and responsibilities on senior surgeons have increased highly

LAPSIM, MIST-VR, LapMentor, and LapVR are few simple procedural simulators with construct validity, that are helpful for training young surgeons through different complicated stages of Laparoscopy surgery. In Pakistan however, the field of virtual reality is relatively new and clinically not explored yet. In this paper, we have simulated Laparoscopic skill exercises using HTC VIVE to give doctors a more real and 360 surgical environment. The scope of

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this study will also be to assess the factors and metrics that could enhance the training or performance of participants. (Buckley, et al. 2012)

2 BACKGROUND

THE first surgical simulator was developed at NASA. It displayed virtual reality for the very first time, with Delp, et al. (1990) being the genius minds behind it. In 1992 the medical simulators replicated the plain human patient models and in 2002 the idea of using VR simulators for educational purposes was accepted worldwide (Lanier, et al. 1992).

Virtual reality is now so advanced that it allows mission rehearsal, in which actual radiological images and patient data is fed to the simulator and it gives young trainee the option to run a complete simulation before performing the procedure on an actual patient. As it is the digital era, surgical simulators are used as teaching tools both in hospitals and in medical institutes. These simulators vary in performance, operations and the metrics used for evaluation of the participants. Although, there have been many ethical concerns discussed by Madary, et al. (2016), relating the extensive use of immersive virtual reality setups. Some participants feel motion sickness or the embodiment effect after using virtual reality systems for a long time. However, the positive impacts of virtual reality training outweigh the minor complains. Hence virtual reality training is being accepted globally. The young doctors are trained using VR head mount devices integrated with the validated laparoscopic simulators available (Palter, et al. 2014).

The McGill University is also working in the field of minimally invasive surgery. An annual course is offered for residents by the minimally invasive surgical program at McGill University. They have also developed their own laparoscopic simulator to objectively measure the performance of surgeons. This simulator consists of a box trainer camera and laparoscopic tools. Derossis, et al. (1998) carried out a research study in which they designed 7 laparoscopic tasks including ‘Peg transfer', ‘Pattern cut' and ‘Suturing'. After the training and repeated measures, all 42 participants showed high improvement in performance. The scoring method was total time taken minus the penalty time for each error made. The evaluation also included precision and speed. Construct validity for this simulator has been performed and the experienced surgeons found this simulator very efficient for training and assessment of young surgeons. As all surgeons may not have access to animal labs, thus the laparoscopic trainer is of great value in surgical practice

The long-term correlation between participant's score and level of training have also been shown over the 2-year interval using the same tasks in McGill laparoscopic simulator by Derossis, et al. (1999). Among the seven tasks first designed, the effectiveness of three tasks was relatively high including ‘Peg transfer', ‘Pattern cut' and ‘Suturing'. This simulator also distinguishes between novices and experts on the basis of test results.

The tasks designed were so effective that these are included in the Fundamental of Laparoscopic Surgery test till date. This test is endorsed by the American College of Surgeons (ACS) and is accredited by CME and Society of American Gastrointestinal and Endoscopic Surgeons (SAGES).

Suebnukarm, et al. (2009) also worked on developing a technique to identify experts and novices, using a VR simulation system that their team developed. The experiment included 10 experts and 10 novices who used the haptic VR to carry out three trails of a crown preparation procedure. The variables used in the independent t-test were mean time to complete the task, mean outcome scores and the amount of force applied. The results showed a clear distinguishment between experts and novices. A similar dental training simulator was developed in 2011 by Rhienmora, et al. that presents an environment for dental training of students using haptic feedback.

The beneficial outcome of VR simulation warm-up has also been demonstrated by Araujo, et al. (2014). This study consisted of 14 residents, among which half of the participating residents underwent a 2 hour long VR simulator training. After the training, all participants carried out a sigmoid colectomy using the pig as a trial subject. The trial results proved the effectiveness of training as the mean score of the study group was better than the control group.

Lack of motivation is also a factor that still needs to be conquered in order to use virtual reality simulators. Van Dongen, et al. (2008) studied that the voluntary use of surgical virtual reality simulators among the students is quite low even if there is a factor of competitive analysis. So this training need to be regulated by the teaching hospital.

The question also arises if the skills acquired through laparoscopic surgery are actually useful and transferable in the real world. J. Torkington, et al. (2001) carried out a research to answer this using a minimally invasive surgical trainer and three groups of students. At the end of the research, the study group showed the best results using both hands, followed by the group trained using conventional methods and the group that received no training had the worst scores.

Another interesting study was carried out by Tanoue, et al. (2008) that focuses on the effectiveness of training for endoscopic surgery. The testing tools included a box trainer and a virtual reality simulator. Fifty-five students participated in this study and the results depicted that the students trained on virtual reality simulator made fewer errors during the procedure. But the students trained on box trainers completed the tasks earlier than the virtual reality simulator group. Therefore the standardized curriculum to train the students for real-time surgery should include training on both box trainer and virtual reality simulators.

AS the box trainer for laparoscopic surgery has already been developed and is being effectively used in Pakistan, we opted for a laparoscopic skill simulator in this regard. So the young doctors and surgeons could have access to both.

3 MATERIALS AND METHODS

TO simulate the laparoscopic skill exercises we chose HTC VIVE as it gives the user the freedom to roam around freely. Hence enhancing the real-time feel. In comparison to other VR technology, the HTC VIVE enables a more advanced immersion and inspection (J. Egger, et al. 2017).

Moreover the accuracy of HTC VIVE and the precision of headset tracking has also been rigorously studied by C. Diederick, et al. (2017). HTC VIVE is not as explored in the medical field as the other VR systems either. HTC vive headmount device can also be used in an Immervise virtual reality setup as the one developed by Huber, et al. (2017).

3.1 Exercises

In this paper, we simulated six exercises that test the basic hand-eye coordination of the participants. These include basic 'Point and touch,' 'Pea on a peg, 'Wire Chaser,' 'Pattern cut, 'Peg transfer,' and 'Loops and wire.'

- **POINT AND TOUCH:**

Point and Touch is the first essential skill exercise, also called level 0. This exercise is done so that the user can familiarize themselves with the instrument and 3D objects. The controller model is replaced with the laparoscopic instrument, as shown in Figure 1. The participant is required to touch various red objects appearing on the screen with the laparoscopic instrument.

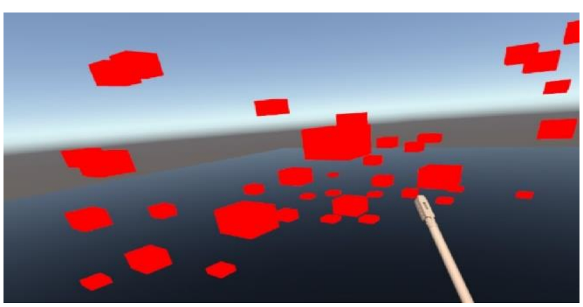

Figure 1. Point and touch

Once an object is touched with the instrument, it disappears. This is a useful exercise to learn the precision of laparoscopic instruments as well as keep track of one's speed. As this is a skill exercise the time to complete the task is a measure of the participant's score.

- **PEA ON A PEG:**

In Pea on a peg, the participant is supposed to pick up four balls and put them in the peg dish. On every successful completion a win alarm is turned on and every time the ball touches the peg or drops on the floor a warning alarm is turned on.

This exercise helps the user to keep his/her hand motions steady and precise. Time to complete the exercise and the number of errors are the scoring measurements.

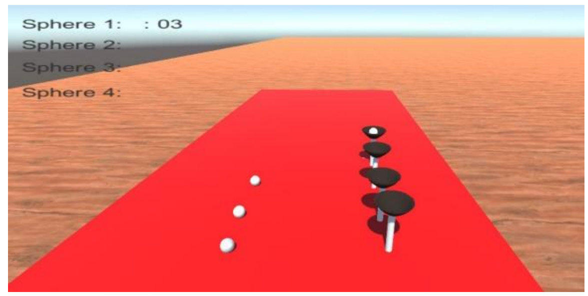

Figure 2 Pea on Peg

Every time the participant picks up a ball the timer starts and it stops when the participant puts the ball in the peg dish successfully. This exercise can be done with alternate hands and the cutoff time is 300 seconds.

- **WIRE CHASER:**

The wire chaser consists of a zigzag wire and a ring. The participant has to move the ring through the wire to the other end without touching the wire at any point. If the participant touches the ring with the wire an alarm is turned on.

This exercise lets the participant practice steady hand movements.

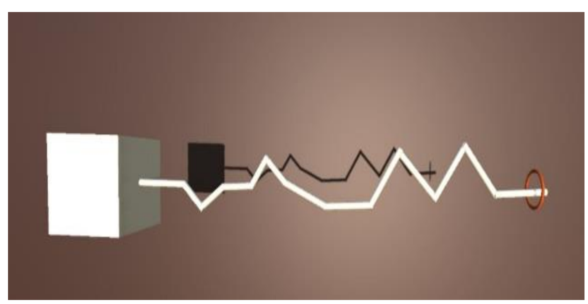

Figure 3. Wire chaser

Several colliders are used in the wire to depict precise collision with the ring. The cut off time for this exercise is 350 seconds.

- **PATTERN CUT:**

This is the second task of FLS. In this exercise, the participant is required to cut cloth in a circle shape of 1mm wide without diverting from the path.

To emulate this we designed a circular path in unity and the participant is required to trace the path using the controller. If the participant diverts from the path inwardly or outwardly an alarm is triggered.

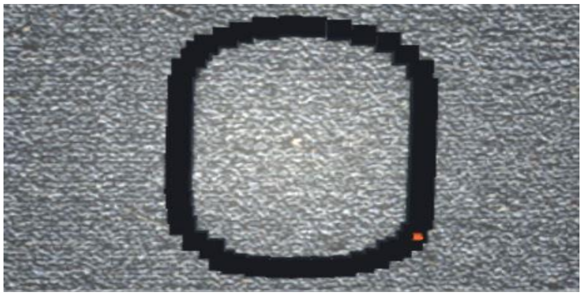

Figure 4. **Pattern cut**

The orange pointer is the starting point of cutting the circle. The size of the circle can be changed according to the level of training a participant has previously received. The FLS standard size of the circle pattern is 4mm. The cut off time to perform this task is 300 seconds.

- **PEG TRANSFER:**

PEG transfer is also the first task of FLS. There are 6 solid objects. The participant is required to transfer the objects to the second set of pegs using the left hand and then transfer them back to the original position using the right hand. We have emulated the same technique.

During the transfer, if the participant touches the peg or drops it an alarm is set on. This task is very effective and correlates with the participant's level of training. The cut-off time to perform it is 300 seconds.

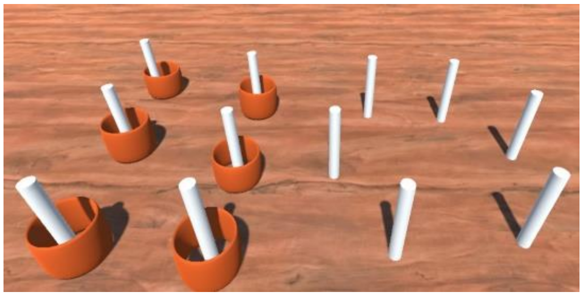

Figure 5. **Peg transfer**

- **LOOPS AND WIRE:**

This exercise tests the steadiness of a surgeon's hands. There are four sets of loops and a small wire, as shown in Figure 6. The participant is required to pass the wire through all the loop sets with precision and without making any error. Anytime the participant touches the wire with the loop an alarm triggers. This a rather tricky exercise.

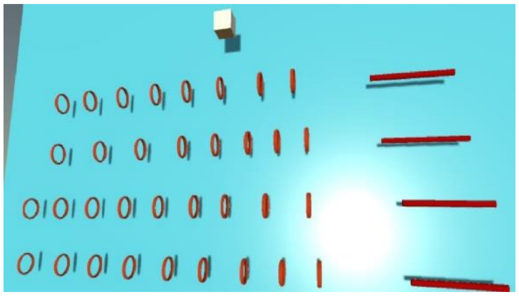

Figure 6. **Loops and wire**

After passing the last wire through the hoop, the participant is required to touch the wire with the white cube on top to stop the timer.

These six tasks are effective in training the young doctors. Currently, in Pakistan, only a few hospitals have access to the laparoscopy box trainers or endoscopy trainer. This manual trainer consists of a box, a monitor screen and laparoscopic tools. A camera is fitted in the box that shows the performance of the participant on monitor screen. All the tasks are performed and evaluated manually.

Figure 7. **Laparoscopy box trainer**

The tasks that we developed can easily be integrated with this box trainer. It will not only make the evaluation easier but also give the participant a 360 virtual feel of the surgical environment using HTC headset.

4 EXPERIMENTS AND RESULTS

WE tested the beta version of our simulator with ten volunteer final year medical students. All the errors made by the participants are noted within our simulator using the time stamp. Furthermore, the total time taken by the participant is also calculated. The program clearly states which object was hit and the number of hits. The ten final year medical students that tested these exercises had received no previous training of laparoscopic surgery

THE students were given a brief introduction of the system, after which each student attempted the exercises. The first time score and time of students were calculated as the baseline score. After which the students were trained on the system for two trails. The score and time of the third trial were used as the final trial result, and the mean of each value was calculated as shown below:

Table 1. Results of Training

Mean Time to Complete the Task of 10 Participants		
Exercise	**Before (sec)**	**After (sec)**
Point and Touch	70	54
Peg Transfer	120	93
Pea on a Peg	69	54
Wire Chaser	44	73
Pattern Cut	56	69
Loops and Wire	160	142

The mean results showed an improvement in the overall time to complete the task. In some tasks as Wire Chaser and Pattern Cut, the time to complete the task increased after the training, but the errors made reduced significantly. Hence our results as in Table 1, showed the positive results net impact on the training of novice students.

5 CONCLUSION

AS this is the era of the digital world, minimal invasive surgery has taken over. This reduces the training hours of young doctors and increases patient safety. Surgical simulator presented in this study helps in creating an operation theatre like environment for young doctors and surgeons to practice the basic skills required for minimally invasive surgery. The series of tasks developed by our technique is objective and provides a sound means for the evaluation of surgical skills obtained by the participants. The technology used in this technique is state of the art. HTC vive surpasses all the VR headsets previously used in medical training, as only it lets the users move around freely in the room, giving an immersive real feel never experienced before.

6 FUTURE WORK AND LIMITATIONS

VIRTUAL reality technology can simulate a surgical process efficiently but there are still a number of challenges to overcome as modern technology is still limited. The graphics used in our virtual reality can model the anatomical structures accurately but are unable to model the kinematic properties hence lacking the realistic touch. The biggest limitation and challenge for our virtual reality simulation is yet the haptic feedback. At the moment VR simulator is not proficient enough to provide solid feedback for the procedures or tasks performed. There is excessive research ongoing in this region and in the future, we plan to develop a haptic device with laparoscopic instruments to attach with the HTC headset. So that the surgeons can have a true feel of the surgical instruments.

The training of surgeons in our virtual reality simulator is carried out in a very controlled way, on the other hand in a real-time surgery there is a number of external factors affecting the decisions of operator e.g. the noise in the operating room and the coordination of surgical staff.

There is also a language barrier in computers and surgeons. A surgeon cannot predict everything that could go wrong during a complicated surgical procedure so that our simulator could train the intern for that situation. Our surgical simulator is man-made and the movements of objects in virtual reality are very calculated whereas in real time the organs are much complex e.g. the bloodstream of every patient might be different depending on the medication one is using or on the level of disease the patient is suffering from. In the future, we will emulate all these factors in our laparoscopic tasks.

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