Virtual Reality for surgical skills training

Figure 1: Example of a Virtual Reality simulator (LapSim®, Surgical Science Sweden AB, Haraldsgatan 5, 413 14 Göteborg, Sweden. Reprint with permission of Surgical Science)

Video game or training tool?

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Laparoscopic surgery is the gold standard for many surgical procedures and is expected to continue to rise. Thus, specific training is of utmost importance. Ethical, economic and educational considerations as well as working hour restrictions have led to the introduction of training outside the operating room, away from the „see one, do one, teach one“ principle. Virtual Reality (VR) allows repeated training with objective feedback without jeopardizing patient safety. A variety of VR simulation modules are currently available including basic and advanced tasks as well as full procedures. Beside conventional laparoscopy, simulation of single site surgery and robotic surgery has recently been adressed. The purpose of this article is to give an overview over the use of simulation for training and assessment purposes.

As compared to open surgery, there are some relevant differences in laparoscopic surgery to be addressed in training programs, such as the reduction of a three-dimensional environment to two dimensions, reduced haptic feedback, limited degrees of freedom, divergation of the visual and motor axis as well as the fulcrum effect, referring to the dissonance between the visual input and proprioceptive feedback, since the tip of the instrument moves to the opposite direction than the surgeon's hand. Once it became evident that training should take place outside the operating room (OR), various options have been evaluated, such as the use of synthetic models in box trainers, cadaveric animal models and anaesthetized pigs.[1]

Ethical considerations and the lack of realism and of objective feedback have led to the introduction of computer simulation, in analogy to aviation. Virtual Reality (VR) simulators allow the interaction with a computer through an interface, the surgical handles (Figure 1). All instruments as in daily practice are available and real time graphics and force feedback allow instant visual and haptic feedback. It is possible to simulate basic tasks, such as camera navigation, eye-hand coordination, two-handed manoeuvers (Figure 2), electrocautery, clipping and cutting as well as advanced tasks, for example suturing (Figure 3) and full procedures, such as cholecystectomy (Figure 4), incisional hernia repair, sigmoidectomy and gastric bypass, including the option of different anatomic variants. Additionally, simulator training for single port and robotic surgery has recently been developed.

Evidence of transfer to the operating room

Various studies support the use of VR for assessment and training of laparoscopic surgery, and the skills acquired using VR seem to transfer into the OR, however the number of high-level evidence studies is limited. A Cochrane review[2] and a meta-analysis[3] focussing on trainees with no to limited experience, two general systematic reviews[4,5] and one focussing on cholecystectomy[6] found an advantage of VR over no training and standard training, in some but not all studies as well over video training. The methodological quality of many studies has however been criticised. Moreover, it has to be considered that many studies were conducted with early-generation software. Further studies should include more patient-relevant outcomes, a longer follow-up and focus on proficiency-based training curricula.

How to structure a training curriculum

Many VR training programs and conducted studies have been focussing on a number of needed task repetitions or a minimum time to spend with such training sessions. It became however evident that training curricula should rather be oriented to achieve a predefined proficiency level.[7] This allows to individualize training prior operating on patients.[8] VR training until achieving expert level has been found to result in significantly fewer errors when assessing the first 10 entire cholecystectomies.[9]

When setting up a curriculum it has as well to be considered that the retention rate after massed practice is lower than after distributed training.[10,11] Moreover, regular supervision is of utmost importance and needs to be considered when evaluating ressource allocation for surgical education. VR training in an unsupervised setting has been associated with similar performance as a control group without training.[12]

A European consensus on a competency-based VR training program has recently been elaborated and published addressing the above-mentioned issues.[13] There, it was proposed to train different levels of difficulties until passing threshold levels twice within one training session prior operating on patients. The maximum length of training session should be set at 45 minutes and trainees failing three times consecutively should retry the exercise later, but continue with another exercise. The thresholds were proposed not to be set at default settings or individual choices, but based on the mean scores of experts plus twice the standard deviation.

Team training

Training should not be limited only to mere technical skills. « Non-Technical Skills for Surgeons (NOTSS) », referring to situation awareness, decision making, communication and teamwork as well as leadership, have been recognized to play an important role in successful patient care.[14] VR may be an integral part of an interdisciplinary OR training and thus contribute to training of non-technical skills.[15]

Economic considerations

In a study evaluating learning curves, a proficiency-based VR training curriculum shortened the learning curve as compared to traditional training.[16] There, the transfer-effectiveness ratio (TER) of VR training was found to be 2.28,

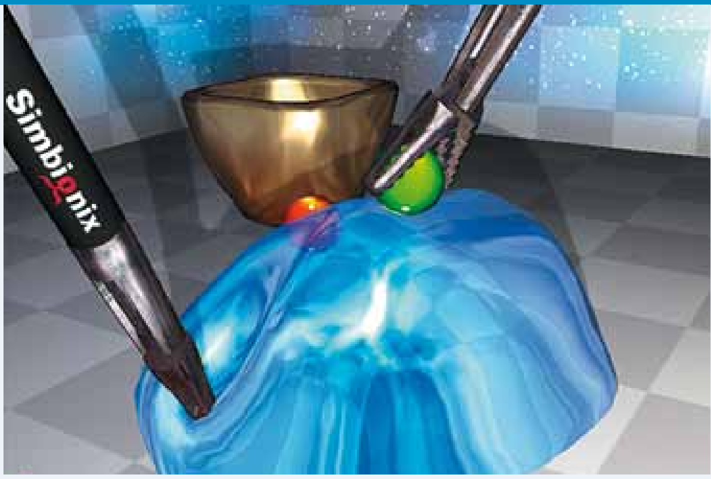

Figure 2: Example of a Virtual Reality basic task: two-handed manoeuver (LapMentorTM, Simbionix USA Corporation, 7100 Euclid Avenue, Suite 180, Cleveland, Ohio 44103, U.S.A. Reprint with permission of Simbionix)

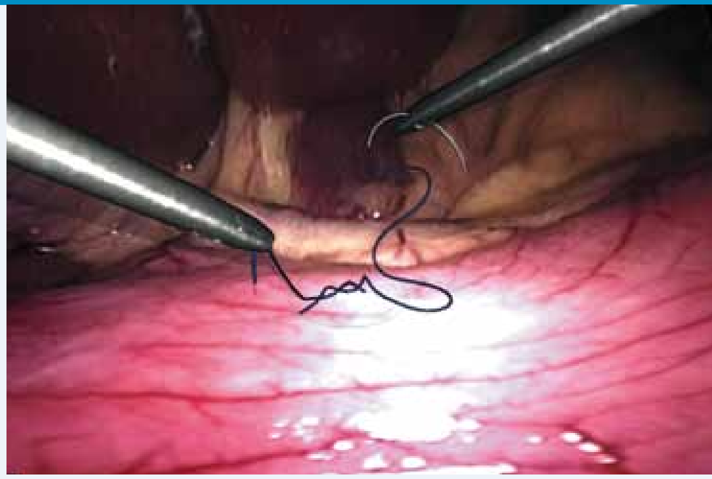

Figure 3: Example of a Virtual Reality advanced task: suturing (LapSim®, Surgical Science Sweden AB, Haraldsgatan 5, 413 14 Göteborg, Sweden. Reprint with permission of Surgical Science)

meaning that per minute VR training, 2.28 cadaveric porcine cholecystectomy training was necessary. Thus, VR may be a cost- and time-efficient approach, although the initial cost of a VR equipment need to be considered.

The comparison of VR to box trainers showed VR to be more efficient (TER of 2.31 versus 1.13), but box trainers to be more cost-effective when training 5 residents.[17] However, for programs with more than 10 residents, VR was more cost-effective. Thus, whereas trainers are confronted with the dilemma of relatively inexpensive box trainers versus VR trainers, the creation of networks to allow more trainees access VR simulators may address this shortcoming.[18,19] The American College of Surgeons has launched an Accreditation Program of Education Institutes for Level I (Comprehensive) and Level II (Basic) Accreditation[18], for which up to date five European Education Institutes have been accredited.[20] The ultimate goal was to create a network of simulation centers offering surgical training. As for Europe, the Section of Surgery of the European Union of Medical Specialists (UEMS) is currently considering an Accreditation Program of Education Institutes.[21]

Virtual reality for skills assessment

The assessment of surgical skills has been addressed in various ways. Based on the experience of OSCE (Objective Structured Clinical Examination), OSATS (Objective Structured Assessment of Technical Skills) has been introduced and validated for the assessment of surgical skills.[22] Another approach to assess technical skills is dexterity analysis, placing sensors on laparoscopic instruments or the surgeon's hand.[1] It has however to be considered that economy of motion is only one of several potentially important outcome measures. Other metrics such as errors, recovery from error, purposefulness of motion, sequence of steps and global performance assessment need to be considered.[23] VR allows instant and objective feedback, including economy of movement and errors. Construct validity has been demonstrated.[13] Additionally, the value of simulation for residents selection has been discussed, however not only considering mere technical skills, but also evaluating communication skills and professionalism.[24]

Video game

The term « serious games » is generally used for games with an educational intent.[25] Today, several video games involving surgical techniques are commercially available. The effect of video gaming - mostly referring to entertainment and not educational games - on laparoscopic performance has been evaluated in several studies. There seems to be a correlation between experience in video games and performance in laparoscopy.[26] However, frequently VR is used as surrogate outcome to measure performance and many studies involve only limited participants numbers. Moreover, the effect seems to be smaller with increased task complexity.[26]

Own research in the field

In our own research, we have evaluated several aspects of training and assessment. In a multivariable analysis involving over 6'000 interventions, we found the surgical site infection rate to be comparable when patients were operated under tutorial assistance versus by independent surgeons.[27] Training in the OR may however have an impact on the duration of surgery. For the example of over 9'000 laparoscopic cholecystectomies, we found surgical training in the OR to be associated with extra time and thus with relevant extra costs.[28]

In training using VR simulators, we found learning curves to be nearly logarithmic and predictable after few repetitions.[29] In a three-group parallel-design randomized-controlled trial (RCT), learning curves were disturbed in the initial phase, when listening to activating music as compared to deactivating or no music.[30] In an RCT of VR versus OR camera training, we found VR training to be time-efficient and the experience to be transferable to the OR.[31] Based on a large prospective database, we were able to define benchmarks important to subsequent training programs.[32] Based on these findings, the Swiss group for Simulations in Surgery (www.swiss-sim-surg.ch) has designed a VR training curriculum, which is offered to all Swiss residents in various parts of Switzerland.

We further evaluated, if there is an association between personality traits and VR performance. In this investigation, we found none of the personality traits, adjusted for gender and surgical experience, to be an independent predictor for VR performance. However, surgeons showed distinct personality traits different from the general population with lower neuroticism, higher extraversion and conscientiousness and in male testees greater openness.[33] The traits are expected to be predictors of team performance, which will be further investigated. To address nontechnical skills such as leadership and communication, we have implemented VR as part of a team training program, involving surgeons and anesthesiologists.[34]

As for assessment using VR, we could demonstrate construct validity, the simulator being able to distinguish between trainees of different levels of experience[35] and found a correlation of VR camera navigation performance with performance at a validated test for spatial skills.[36] Additionally, in a VR study involving children aged 8 to 12 years, we found lowest performance in children with low experience in video games, followed by those with high experience, residents and board-certified surgeons.[37] In a survey conducted involving over 500 surgical residents, we found the majority of them to accept VR as training tool.[38] Several other studies are currently under review or ongoing.

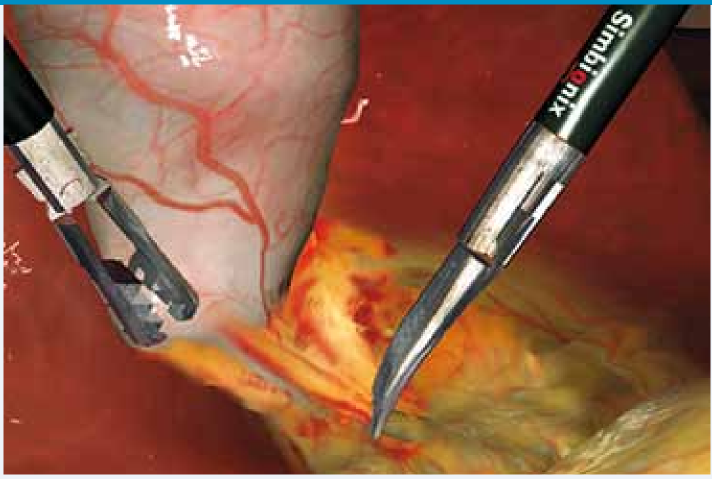

Figure 4: Example of a Virtual Reality full procedure: cholecystectomy (LapMentorTM, Simbionix USA Corporation, 7100 Euclid Avenue, Suite 180, Cleveland, Ohio 44103, U.S.A. Reprint with permission of Simbionix)

Outlook

Beside the development of new modules for full laparoscopic procedures and single site surgery, training in robotic surgery will further be addressed. Currently, robotic surgery may be trained using a converted VR laparoscopy simulator; a simulator applying the same kinematics as the robot[39]; or by using the recently developed VR simulator integrated in the robot using the original console as interface.[40] These systems will be subject of further validation studies in the near future.

Another relevant development will be the development of patient-specific simulation. This is closely tied to surgical planning and surgical rehearsal and may be supplemented by a „preoperative warm-up" immediately prior surgery.[24] The technique of augmented reality (AR) allows intraoperative surgical navigation superimposing a reconstructed 3D image on the live surgical open or laparoscopic view and thus provides insight beyond the direct surgical view.[41] Whereas in environments with fixed anatomic landmarks within a bony frame and minimal organ motion AR can be more easily applied, the automated tracking and correction for organ motion and deformation during intra- and retroperitoneal surgery remains a challenge for routine use.[41,42]

Conclusions

In conclusion, VR is not only a mere video game, but an important supplement to traditional training, allowing training outside the OR in a standardized setting without jeopardizing patient safety and providing instant objective feedback. Although it may not replace the OR, it is especially relevant in laparoscopic novices. VR training should be integrated into a proficiency-based and supervised training curriculum.

Referenzen auf: www.swiss-knife.org

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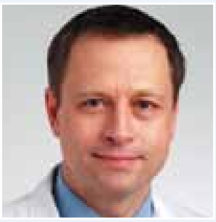

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