

Is virtual reality simulation an effective training method in surgery?

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Reports of adverse outcomes caused by technical errors during surgery and better understanding of the components of surgical competency have highlighted the importance of teaching surgical technical skills in a safe and pedagogically efficient environment.¹ This need has been further emphasized by the rapid development of new approaches, such as minimally invasive surgery and endoluminal therapies, both of which require proficiency with sophisticated technical skills. The old approach of 'see one do one, teach one' is no longer acceptable to either the surgical profession or to the well-informed and demanding public. New tools have been developed for teaching and assessing technical skills outside the operating room using virtual reality simulation, which has been applied for many years with great success in many industries including aviation and the military.

Traditionally, surgical virtual reality simulators facilitated training in basic skills relevant for laparoscopic surgery by enabling users to perform maneuvers using abstract graphics (low-fidelity simulation). With software development, the simulators now enable users to perform complete procedures with the added simulation of rare anatomical variations and various pathological conditions. The interface of these high-fidelity systems enables the surgeon to 'feel' the tissue (haptic feedback). The realism, however, of these simulated procedures is still suboptimal, and the high cost of virtual reality simulators limits their widespread distribution. Furthermore, the advantages of the high-fidelity, high-cost systems have not yet been demonstrated and future studies are needed to establish the potential advantages of procedure-specific simulation.

Laparoscopy poses significant psychomotor challenges to the surgeon because of the loss of three-dimensional depth perception and the fulcrum effect of the body wall on instrument handling.² Virtual reality simulators facilitate repeated practice of standardized tasks to help surgical trainees become familiar with specific

psychomotor skills before performing procedures in the operating room, which is a stressful and high-cost environment. Furthermore, the simulator software often incorporates extensive teaching guidance, eliminating the need for an instructor and, therefore, offering a flexible training schedule to fit the busy day of a surgical trainee. The simulators also offer the unique possibility to quantify surgical performance on the basis of objective measures, which provides an unbiased assessment of surgical performance.³

Despite these obvious advantages, there are still areas that require improvement. Most of the available high-fidelity systems have undergone substantial developments in both graphics and haptics; however, their level of realism requires refinement. The objective measures used in these systems to assess performance are excellent; however, they are difficult to interpret by the trainee and this limits their value as a source for constructive feedback. A major disadvantage is the high cost of simulator systems, which poses a significant challenge for many institutions. Finally, most simulator systems provide training in psychomotor skills only and do not address the other components of surgical competence (i.e. knowledge, decision making and communication).

Validation of virtual reality simulation as a surgical training tool requires evidence of the transferability of skills acquired in the virtual reality environment to the operating room. Two studies have compared virtual reality training versus conventional training and have shown that surgical trainees who undergo simulator training outperform their colleagues without simulator experience.^{4,5} In a randomized, controlled trial of 16 surgical trainees, those who had received virtual reality training for a laparoscopic procedure were faster, made fewer errors and showed greater economy of motion compared with those who had not received such training. Virtual reality training, therefore, contributes to the development of skills

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relevant for real procedures and might shorten the learning curve for new procedures. Most educators agree that virtual reality simulators are efficient training tools in laparoscopic surgery and should be widely implemented in the surgical training curricula.

If applied to a residency curriculum, virtual reality assessment can be used for continuous monitoring of a trainee's performance as well as for early intervention when the speed of a trainee's skill acquisition is suboptimal. Studies have demonstrated that constructive feedback based on objective criteria contributes to improved learning and has the potential to shorten the learning curve of a procedure in the operating room.⁶

There is a considerable amount of evidence confirming that virtual reality simulators provide an instantaneous, unbiased, reliable and valid assessment of technical skills for laparoscopic surgery. Face and construct validity (the degree of resemblance between the system and the procedure it intends to simulate and the ability of the system to discriminate between individuals from different experience levels) have been demonstrated for most of the commercially available virtual reality systems. The most powerful evidence of validity—predictive validity (the extent to which the scores on a test are predictive of actual performance in the operating room)—has so far been shown in two observational studies.^{7,8} This substantial evidence on the validity of virtual reality simulation has been summarized in a consensus document by the European Association of Endoscopic Surgery who indicated level 2 recommendations for the assessed simulator systems.⁹ As evidence continues to evolve, clinicians will observe validation of curricula for resident training as well as certification and recertification of practicing surgeons on the basis of objective assessment. Virtual reality simulation will without doubt play a major role in these processes.

Most of the commercially available simulation systems are offered with a broad range of settings with no predefined proficiency criteria and no information on the intensity or duration of training needed to achieve technical competency. In order to standardize the process of virtual reality training, there four questions that must be addressed. Firstly, what should the difficulty setting be set at for each task? Secondly, has the validity for each difficulty setting been

established? Thirdly, has the learning curve for each setting and task been assessed? Finally, have performance proficiency criteria been established for procedures on the basis of expert assessment? An evidence-based proficiency curriculum can be designed only after each of these questions has been answered.

Previous studies have investigated and validated curricula for simulator training in basic laparoscopy.¹⁰ It should be highlighted, however, that virtual reality simulators are mainly technical skills trainers and a comprehensive residency curriculum should include additional tools such as box trainers, animal models, cadavers and human patient simulators.¹¹

Virtual reality simulation will continue to have an important role in the training of basic and procedure-specific skills in various surgical specialties, and endoscopy and endoluminal therapies. Future efforts should investigate the impact of this type of training on the quality and speed of skills acquisition of trainee surgeons to facilitate the production of excellent surgeons in a safe and pedagogically supportive environment.

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Competing interests

The author declared no competing interests.