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Virtual operating room for team training in surgery

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Abstract

BACKGROUND: We proposed to develop a novel virtual reality (VR) team training system. The objective of this study was to determine the feasibility of creating a VR operating room to simulate a surgical crisis scenario and evaluate the simulator for construct and face validity.

METHODS: We modified ICE STORM (Integrated Clinical Environment; Systems, Training, Operations, Research, Methods), a VR-based system capable of modeling a variety of health care personnel and environments. ICE STORM was used to simulate a standardized surgical crisis scenario, whereby participants needed to correct 4 elements responsible for loss of laparoscopic visualization. The construct and face validity of the environment were measured.

RESULTS: Thirty-three participants completed the VR simulation. Attendings completed the simulation in less time than trainees (271 vs 201 seconds, P = .032). Participants felt the training environment was realistic and had a favorable impression of the simulation. All participants felt the workload of the simulation was low.

CONCLUSIONS: Creation of a VR-based operating room for team training in surgery is feasible and can afford a realistic team training environment.

The benefits of simulation in surgery are well documented, allowing trainees to achieve proficiency in shorter times, acquire news skills, and retain skills, all in environments that are inexpensive, reproducible, and safe.[1–12] With the abundance of evidence to support simulation, surgical residency programs have rapidly adapted inanimate training into their curricula, with most programs staffing full-time simulation centers.[4,13–15] The American College of Surgeons has recognized the value of simulation in surgery and has developed an extensive accreditation program for simulation centers.

Most of the focus in surgical simulation has been on task training of surgical skills, ranging from knot tying to chest-tube insertion to flexible endoscopy. Perhaps the most salient example is laparoscopic surgical skill training, whereby a systematic course of box trainer–based laparoscopic tasks has proved so effective, and the course has been mandated for certification by the American Board of Surgery.[16] However, technical skill is only one aspect of being an effective

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surgeon. Furthermore, the surgeon is only one part of the team necessary to deliver effective surgical care.

Successfully performing an operation requires the coordinated teamwork of the surgeon, anesthesiologist, nurses, hospital staff, and clinical information systems. Recognizing the importance of teamwork in the operating room (OR) has led educators to move from the relatively simplistic training of surgical tasks to the more complicated world of whole team training in the surgical environment.[17–19] Team training in surgery involves creation of a simulated OR, in which combinations of real equipment coupled with mannequins and computerized integration allow a human team to recreate real-life operative scenarios. The American College of Surgeons has created a series of standardized OR situations that can be used in training.[16]

Several groups have reported success with multidisciplinary OR simulation.[20–22] Others although have had difficulty executing such simulation secondary to cost and space requirements.[13,23] Furthermore, with limited duty hours, it can be difficult to assemble the necessary team members to undergo the training. These factors have limited the widespread use of team training simulations in surgery compared with the relatively simple task training that has been widely adapted.

We hypothesized that VR software can offer realistic team training environments that overcome some of the current limitations. Therefore, we proposed to create a multiuser interactive environment in which both team-based skill coupled with surgical decision making can be simulated, critiqued, and evaluated. Lockheed Martin Corporation (Oswego, NY), well known for its military-based simulation and training programs, has developed a VR-based environment for use in medical training called ICE STORM (Integrated Clinical Environment; Systems, Training, Operations, Research, Methods). The objective of this pilot study was to determine the feasibility of modifying the ICE STORM VR OR to simulate a standardized surgical crisis scenario and evaluate the simulator for construct and face validity.[24,25]

Methods

The existing ICE STORM platform contains all the equipment and personnel necessary to simulate a variety of scenarios in a virtual OR. A core team of researchers from both Lockheed Martin and Weill Cornell Medical College (New York, NY) was established to modify ICE STORM to simulate an intraoperative crisis scenario. In addition to modeling the necessary elements of this crisis scenario, additional software was created to allow a human proctor to serve as an interface between study participants and the virtual world. The interface software used a standard iPad (Apple Inc., Cupertino, CA) to allow a human proctor to modify the simulation environment as necessary during the course of the training exercise, depending on the participant's responses.

The laparoscopic troubleshooting module is a team training scenario published by the American College of Surgeons and has been previously validated.[16] The full module is beyond the scope of this pilot project and entails a comprehensive team of surgeon, assistant surgeon, nurses, and anesthesiologist working through several crisis situations while performing a standard laparoscopic operation. In this project, the focus was narrowed to a small portion of the module, called "loss of laparoscopic visualization." This scenario was then programmed into the modified ICE STORM platform.

In the "loss of laparoscopic visualization" scenario, the team was performing a laparoscopic cholecystectomy and the laparoscopic monitor suddenly went dim. It was the job of the operating surgeon to troubleshoot the problem and return the monitor to working form. There were several possible problems that the participant, functioning as the operating surgeon, had to identify and check to restore function to the monitor. Each participant was required to perform 4 mandatory treatments: (1) check camera box and cord; (2) check light-source box and cord; (3) check (clean/inspect) or replace laparoscope (use spare); and (4) exchange and use spare camera. Participants were evaluated by time to completion of the simulation. Participants were given a "pass" if they completed all mandatory treatments in less than 270 seconds. This number was based on preliminary analysis of test subjects.

Participants, acting as the surgeon, interacted with the VR world using the Gyration Air Mouse (SMK-Link Electronics, Camarillo, CA; Supplementary Fig. 1) to manipulate the surgeon avatar and interacted with the human proctor administrating the study by simply speaking aloud. The proctor then used the proctor-tool software on a standard iPad (Apple Inc.) to make modifications to the VR world (eg, participant instructs nurse to replace the laparoscope, the proctor enters the appropriate command, and then the nurse avatar replaces the laparoscope). Successful completion of the module was achieved when the participant identified all 4 of the critical elements that could lead to loss of visualization. No matter what order a participant identified the element, the simulation would not end until all 4 components were identified and correctly acted on. This concept, known as the "full cycle test," ensured that all participants would demonstrate a complete understanding of the most critical elements of the troubleshooting scenario and eliminated the possibility that the participant could end the simulation simply by picking the "correct" cause of failure on the first try.

Metric data from the simulation exercise were used to evaluate the construct validity of the virtual system. Three methods were used to determine the face validity: Likert scale questionnaires (Table 1), the Bedford Workload Scale (Supplementary Fig. 2), and the modified NASA-Task Load Index (NASA-TLX) scale (Supplementary Fig. 3). Subjects included attending surgeons (experts) and residents and medical students combined (trainees). Statistical analysis was conducted using SPSS 12.0 statistical software (IBM,