

Virtual Reality Environments in Surgical Training – Introducing the Pre, Trans and Postoperative Virtual Environment (OPVIR)

Ambientes de Realidade Virtual Aplicados ao Ensino da Cirurgia – Apresentação do Ambiente Virtual Pré-, Trans- e Pós-cirúrgico (OPVIR)

ROSILENE JARA REIS, PHD; AMARILIO VIEIRA DE MACEDO NETO, PHD; MÁRCIO SARROGLIA PINHO,
PHD; PATRICIA ALEJANDRA BEHAR, PHD; MARIA ISABEL EDELWEISS, PHD

Graduate Program in Medicine: Surgery and School of Education, Universidade Federal do Rio Grande do Sul (UFRGS), Brazil. Graduate Program in Computer Science, Pontifícia Universidade Católica do Rio Grande do Sul (PUC-RS), Brazil.

ABSTRACT

Objectives: To briefly describe virtual reality simulators used as a tool in the teaching of undergraduate medical students and introduce OPVIR, the pre, trans and postoperative virtual environment developed by this group. **Research report:** In virtual reality systems used for the teaching and training of surgical principles, or any other invasive procedure in which students are expected to actively participate, the more closely the virtual model and reality resemble each other, the more intense the training experience. OPVIR is a virtual reality pretraining education tool for the teaching of basic surgical principles in medical school. The system requires students to perform a wide range of tasks, from choosing the right size gown, positioning the operating team around the surgical table, choosing instruments and starting a thoracotomy to completing a pathology requisition form. **Preliminary results:** In a preliminary evaluation of OPVIR, 15 medical students rated the overall virtual experience as satisfactory or highly satisfactory (scores 7 to 9 on a 10-point scale). **Discussion:** Our preliminary results suggest that OPVIR is useful as a pretraining education tool for medical students who have never been in contact with a surgical unit. Virtual reality systems, once integrated with other curricula and teacher support, may be a solution for medical education programs.

Key words: surgical instruction; medical students; virtual reality systems.

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INTRODUCTION

Traditional methods of teaching surgical skills used in medical schools worldwide are giving way to new information technologies; one of the most important of these new technologies is virtual reality (VR). Traditional teaching strategies based on training in the operating room are dependent on hospital volume of surgical procedures and use subjective assessment. Instruction should be based on more objective, precise evaluation criteria with immediate performance feedback.

With the introduction of new teaching technologies, curriculum changes should be dynamic and adaptable to new medical demands. Based on

this premise, the Accreditation Council for Graduate Medical Education (ACGME) and the American Board of Medical Specialties (ABMS) defined, during the 2001 consensus,¹ the following paradigm shifts in the teaching and training of surgical procedures in medical schools, focusing on six core competences (knowledge, patient care, interpersonal and relationship skills, professionalism, practice-based learning, and system-based practices):

- Surgical curricula should be standardized;
- Objective assessment of student performance should be conducted at the end of each level;
- Criteria based on levels of proficiency should be applied to surgery residents.

Following the same line of arguments as for standardized guidelines, the American College of Surgeons (ACS), since June of 2008, has established as mandatory the use of simulation in all surgery residency programs, aiming to establish surgery simulation centers in order to ensure high-quality services.²

Taking all this into consideration, the Graduate Program in Surgery at a major federal university in southern Brazil has established a new research line focused on the development of VR tools. The first task of this interdisciplinary team was to develop a simple VR tool to introduce medical students to a surgical environment: a pre, trans and postoperative virtual environment, dubbed OPVIR.³

Within this context, the objective of the present paper is to briefly describe VR simulators currently used in medical training and introduce OPVIR, the pre, trans and postoperative virtual environment developed by this group.

SIMULATORS USED IN MEDICAL TRAINING

Simulators — also known as human patient simulators (HPS) — may be physical models, computer-based, or hybrids.⁴ Simulators based on physical models have a reasonable degree of realism. However, these models have limitations, such as the fact that they can simulate only isolated body parts, hindering a complete illusion of reality. In addition, since these are inanimate models, they do not provide any type of feedback or objective performance scores. Teaching then relies on assistance and feedback from experienced instructors (Figure 1).

Computer-based simulators are an attractive alternative, since they provide experiences that more closely resemble reality. VR, by promoting a real-time tridimensional interaction with the computer, enables some types of interaction such as manipulation and cutting of organs of the human body. Hybrid simulators

combining physical models with computers, in turn, may be used for simulations that are difficult to be reproduced only in the machine, such as tissue texture and organ shape.

Regarding manipulation by the user, simulators may be either simple or complex. Simulators that focus on the precise positioning of a needle or instrument are the simplest models. Simulations are performed through a single movement, such as needle insertion for anesthetic blockade or central or peripheral vascular access. Due to this characteristic of simplicity, virtual representation closely resembles reality, and the inclusion of tactile stimuli is feasible with a high degree of fidelity. These simulators are already commercially available; one example is the Immersion Medical CathSim Vascular Access Simulator.

With a higher level of complexity, simple manipulation simulators can simulate complete minimally invasive surgical procedures. Basic tasks provided by this resource, such as manipulation of a flexible endoscope, are relatively simple and direct. Once tasks have been completed, several nuances of instrument manipulation may be practiced. Specific tasks are developed to teach each step of the procedure individually and in an incremental manner so that some tasks can only be performed if more basic ones have been mastered. Some simple manipulation simulators are commercially available, such as the paranasal sinus surgery simulator; however, these simulators are still not widely used because they are too expensive and can be run only in high-performance computers.

Unlike the simulators mentioned above, complex manipulation simulators have not yet achieved a high degree of development and commercial availability, although they have been extensively studied. These simulators are tailored to teaching complex tasks, such as suturing blood vessels, and represent such tasks visually, with force and touch feedback. All this makes these applications



Figure 1 - Simulator based on a physical model.

computationally extensive. Although not “photorealistic,” images have a reasonable degree of realism, and the interactive realism attained is good enough to make the experience acceptable for the teaching of certain skills using both hands.

The first complex manipulation simulator, the Minimally Invasive Surgical Trainer-Virtual Reality (MIST-VR), was developed in 1997. Its use has been validated as effective in improving the performance of students who have trained with the simulator, as well as in the evaluation of psychomotor techniques between experienced and inexperienced surgeons.^{5,6} It is important to highlight that MIST-VR does not simulate a surgery, but rather graphically simple tasks, such as manipulation of a sphere to be placed inside a cube. However, these tasks use the same techniques employed in an actual surgery.

Another example of a complex manipulation simulator recently developed is the anastomosis simulator, which simulates the suturing of tubular structures. (Figure 2).⁶

BERKLEY and cols.⁷ presented a suturing simulator that may be classified as complex manipulation. This model simulates, with reasonable realism, tactile feedback and deformation through finite element modeling: an accurate methodology for the design and testing of prototypes widely used in the industry. According to the authors, the use of these elements enables a realistic simulation of tactile feedback and real-time deformation of tissues. At the current stage, tactile feedback is obtained using a Phantom. Suture knots, however, are not tied by the user, but rather by pressing a key (Figure 3).

The last type of simulator used in medical training permits the student to perform an integrated procedure involving several different tasks, such as cutting, dissection, and anastomosis, combined in a complete surgical procedure. Different tissues, organs, and surgical instruments add to the complexity of the simulation environment. Although these simulators do not generate high-quality images, the interaction is realistic and provides an opportunity to practice a complete procedure. These simulators may be mannequin-based, computer-based, or hybrid. An example of an integrated procedure hybrid simulator is the knee arthroscopy simulator.⁸ This simulator provides a detailed representation of the internal anatomical structure of the knee joint, and displays several different instruments used to perform various procedures.

Another application of simulators includes surgical planning, in which experienced professionals can simulate a procedure and evaluate the consequences of their decisions in a safe environment. McCLOY and STONE⁹ stated that VR technologies enable the procedure to be performed and results to be analyzed before the surgery is carried out. Thus, surgical approaches can be practiced and optimized, increasing the chances of success. In order to accomplish the surgical planning, it is necessary that actual images of the organs to be operated be used in the simulators. An example of a surgical planning system is the hepatectomy simulator developed by BENES and cols.¹⁰ for the planning of liver surgery (Figure 4).

PRE, TRANS AND POSTOPERATIVE VIRTUAL ENVIRONMENT – OPVIR

OPVIR is a virtual environment system developed to introduce medical students to operating

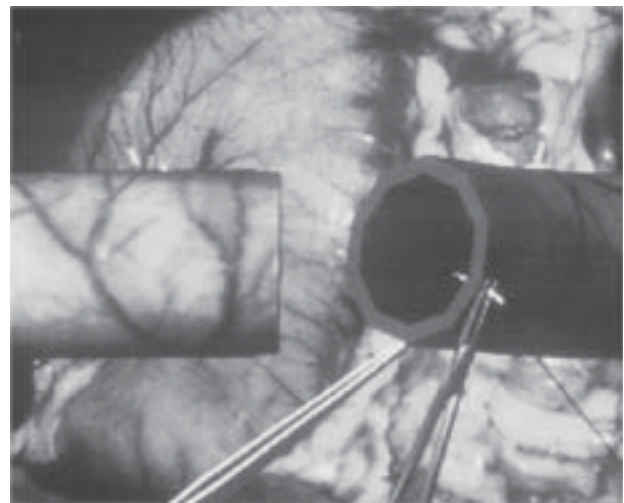


Figure 2 - Anastomosis simulator.



Figure 3 - Images of a suturing simulator.

routines. During a 40-minute immersion, students navigate and interact in this tridimensional synthetic environment by performing tasks covered in the Basic Surgical Techniques course. The system requires students to perform a wide range of tasks, from choosing the right size gown, positioning the operating team around the surgical table, choosing instruments and starting a thoracotomy to completing an anatomic pathology requisition form. The tasks were designed so that they could be easily performed. As the virtual sequence proceeds, the student receives guidance in the form of tips. When all the steps are completed, a report is generated which informs the score (correct or incorrect choices) and the time required to complete the sequence. Surgical instruments are positioned using data input devices such as a mouse, keyboard or trackers.

Table 1 describes the main scenarios featured in OPVIR.

Preliminary assessment

Fifteen medical students (age ranging from 21 to 24 years) without previous surgical experience, who had never been exposed to a virtual environment but used a personal computer (PC) regularly tested the system and filled out a 17-question assessment questionnaire focusing on system usability. All students signed an informed consent form and were interviewed concerning demographic attributes (age, gender and others).

After completing the questionnaire, students were asked to rate the program from 0 to 10 (subjective assessment) and to comment. Separately, a group of 12 professionals, including five physicians, five

computer scientists and two educators were asked to try the system and then rate it.

PRELIMINARY RESULTS

The answers provided by 15 students are summarized in Table 2.

The overall subjective scores assigned to the system by the students (from 0 to 10) were 7 (one student), 8 (four students) and 9 (ten students). Suggestions for improvement referred to more guidance (six students), improving texts and legends (five students), and more emphatic voiceovers (two students). The reasons for approval were: you learn while you play (one student); different from traditional methods (four); easy to learn (two); makes you curious (six); grabs attention (one); diversity of resources (one).

The overall subjective scores given to the OPVIR system by the 12 professionals were 9 or 10 by the five physicians; 8, 9 or 10 by the five computer analysts; and 8 by the two educators. Therefore, the subjective score assigned to the software by the professionals was similar (e" 8).

DISCUSSION

There seems to be a consensus in the literature that computer-based tools and VR systems are useful for medical training, especially in surgery. As pointed out by GALLAGHER and col.,¹¹ the acquisition of skills is best achieved if pretraining education is provided to ensure that the learner knows what needs to be done. Of the eight steps proposed by these authors as part of a well-thought curriculum, OPVIR can cover, even if superficially, the first five.

Teaching of surgical skills represents a challenge both for teachers, who take to the operating room their experience and knowledge to deal with unexpected situations, and for inexperienced students, who are still trying to learn the basic steps of a surgical procedure. Students should not only understand cognitive problems underlying surgical procedures, but also master technical aspects, with constant training in a surgical environment. Different from other cognitive functions in medicine, surgical skills require practical experience, preferably under the supervision of an experienced surgeon.

Patients undergoing a surgery want to trust their surgeon and believe that the physician can

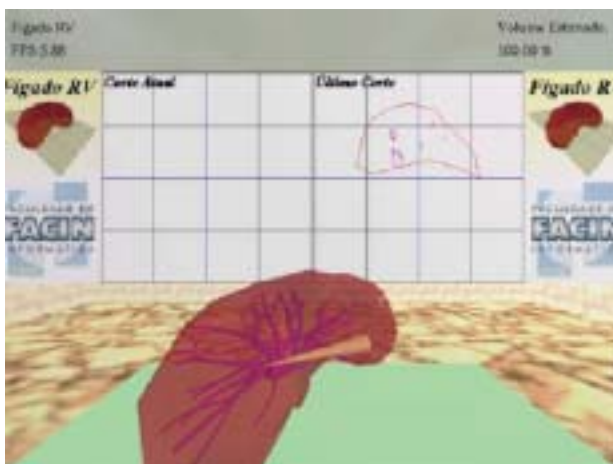













Figure 4 - Planning environment for liver surgery.

Table 1 - *OPVIR scenarios.*

Scenario/setting	Task	Image
Introduction	Welcome and instructions	
Waiting room	Providing information to relatives	
Locker room	Choosing a gown of the right size	
Locker room	Identifying the correct locker and learning how to dress correctly	
Washroom	Learning how to wash and scrub	
Operating Room	Positioning the patient on the operating table for a thoracotomy	

Continuation ahead

Continuation of table 1

Scenario/setting	Task	Image
Operating Room	Positioning surgical team and assigning responsibilities	
Surgical instrumentation	Identifying basic surgical instruments for the thoracotomy	
Operating Room	Opening the chest, identifying anatomic landmarks and performing inspection maneuvers	
Recovery room	Transporting the patient to the recovery room	
Records	Operative report, filling out a anatomic pathology requisition form and a prescription	

perform the proposed surgery without causing the patient any injury. This poses a dilemma for both teachers and students. Surgical instructors must be judicious when allowing inexperienced students under

their supervision to familiarize themselves with surgical steps (judgment skills and technical experience), they have a duty to protect their patients from inexperience errors.

Table 2 - OPVIR Evaluation Scores (n = 15 medical students).

(Worst)	Score				
	0	1	2	3	4 (Best)
Evaluation item					
Readability	2				13
Are texts clear				4	11
Are long texts adequate			5	8	2
Are icons self-explanatory			2	12	1
Quality of sounds and video				1	14
Integration of videos and audios to system and contents					15
Are scenarios pleasant					15
Are scenarios realistic					15
Are voiceovers clear					15
Was the narrator's voice pleasant		1	1	6	7
Clarity of legends and reading time				9	6
Effectiveness of navigation instructions		6			9
Clarity of theme				7	8
Relevance of topic					15
Is the system interesting			1	2	12
Are sound resources pleasant		1	1	5	8
Do sound resources contribute to realism			3	7	5
Are tasks easy to understand			2	12	1
Are tasks easy to perform			1	7	7
Degree of approval					15

Technology has become an unavoidable part of both our daily lives and medicine specifically, and it would be foolish not to prepare students to use it. Therefore, the use of simulators and virtual technologies may be a natural solution for medical education programs.

CONCLUSION

Even though a realistic representation is not considered to contribute to all training experiences,¹¹

we believe that virtual environments, once integrated with other curriculum contents and teacher support, may translate into a successful educational experience.

Our preliminary survey results suggest that OPVIR is viewed as a useful pretraining education tool for medical students who have never been in contact with a surgical unit. A study is currently underway to validate both the tool and its efficacy for pretraining education.

RESUMO

Objetivos: Descrever brevemente os simuladores em realidade virtual utilizados como ferramenta de ensino nos currículos de graduação em medicina e apresentar o ambiente virtual pré-, trans- e pós-cirúrgico (OPVIR) desenvolvido por este grupo. Relato da pesquisa: Nos sistemas de realidade virtual para ensino e treinamento de cirurgias, ou qualquer procedimento invasivo onde o aluno participa ativamente no meio, quanto mais próximo da realidade esse modelo virtual for, mais intensa será a experiência de aprendizagem. OPVIR é uma ferramenta de ensino pré-treinamento em realidade virtual para apresentar rotinas cirúrgicas a estudantes de medicina. O sistema requer que os estudantes realizem uma ampla variedade de tarefas, desde a escolha do tamanho correto da roupa, o posicionamento da equipe cirúrgica em volta da mesa de cirurgia, a escolha dos instrumentos e o início da toracotomia até o registro do exame anatomopatológico. Resultados preliminares: Em uma avaliação preliminar, 15 estudantes de medicina avaliaram a

experiência virtual global como satisfatória ou muito satisfatória (escores de 7 a 9 em um escala de 10 pontos). Discussão: Os resultados preliminares sugerem que o OPVIR é útil como ferramenta de ensino pré-treinamento para estudantes de medicina que nunca estiveram em um bloco cirúrgico. Os sistemas de realidade virtual, uma vez integrados a outros conteúdos curriculares e ao suporte de professores, se transformarão em uma solução para os programas de ensino médico.

Descritores: instrução cirúrgica; estudantes de medicina; sistemas virtuais.

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Address Correspondence:

ROSILENE JARA REIS

Rua Portuguesa, 259

Partenon, Porto Alegre, RS

90650-120 Brazil

E-mail: rjreis@terra.com.br

Telephone number: (+55) 51-9998 2612, (+55) 51-3012 0575

Fax: (+55) 51-3012 0575