Simulation for Neurointervention

Simulators serve as a valuable training aid for new neurointerventional fellows and others who may be inexperienced with catheter-endovascular techniques.

BY CHRISTOPHER S. OGILVY, MD; RODNEY M. SAMUELSON, MD; BERNARD R. BENDOK, MD; KENNETH V. SNYDER, MD, PhD; GURSANT S. ATWAL, BS; ALEXANDER M. MORRISON; ADNAN H. SIDDIQUI, MD, PhD; L. NELSON HOPKINS, MD; AND ELAD I. LEVY, MD

Over the past 2 decades, virtual reality (VR) simulation has evolved in a number of fields as a way to train individuals for given jobs and situations, as well as maintain expertise. Simulators have long been used in aviation and have become increasingly sophisticated as computer technology has advanced. In addition to flight simulation in aviation, ground combat simulation has also evolved in the US Military. Other areas where simulators are used on a regular basis include nuclear power plants and professional automobile racing (stock car racing and Formula One racing). In medicine, simulators have been used in anesthesia for several years. Simulators have evolved as a way of teaching basic techniques (eg, intubation and line placement) to anesthesiologists, as well as to train for rare clinical circumstances in the operating room. In addition, simulators are used for board certification and maintenance of certification.

In the field of endovascular therapies, simulators have been used for a number of years. Over the last few years, simulators have been developed to produce excellent haptic feedback such that the tactile experience of manipulating an intravascular catheter is amazingly similar to real-life situations. During this interval of development, training standards have been changed so that work hours have been reduced; therefore, endovascular training may have to adapt to a new paradigm. Several studies have shown enhanced proficiency with simulator training for surgical procedures as well as endovascular techniques.[1-6] Simulation offers advantages over traditional surgical training that include absence of risk to the patient and the ability to immediately repeat tasks with the option of altering anatomic features. The question remains whether simulation training provides real-world benefit for training proceduralists who are inexperienced with endovascular techniques.

SIMULATION

Simulation is defined as a technique to replace or amplify real experiences with guided experiences, often immersive in nature, that evoke or replicate substantial aspects of the real world in a fully interactive fashion.[1]

1. Gaba DM. The future vision of simulation in health care. Qual Saf Health Care. 2004;13(suppl 1):i2-10.

THE BUFFALO EXPERIENCE

The University at Buffalo Department of Neurosurgery uses the Procedicus Vascular Interventional System Trainer (VIST) (Mentice AB, Gothenburg, Sweden) as part of the initial training for neuroendovascular fellows without previous catheter-based angiography experience. During the first week of fellowship, approximately 25 simulated angiograms are completed. These 25 procedures are not counted toward the recommended 100 cerebral angiograms required for credentialing purposes.[7] This preliminary training emphasizes diagnostic angiograms and navigation of diagnostic catheters through the aortic arch and great vessels. There are no restraints with respect to procedure length, patient risk, or operator safety as regards the radiation dose. This separation from patient care allows the freedom to work through the process, gain experience with devices, and experiment with various forms of technique.

The counterintuitive push or pull actions of a Simmons-2 catheter (Cordis Corporation, Warren, NJ), which is a commonly used preformed catheter that has applications in cerebral angiography and endovascular interventions, provides a good model for the usefulness of VR simulation. The catheter must initially be reconstituted, either in the aortic arch or in the left subclavian artery. A specific technique is then required for cannulation of each of these major vessels. The basic skills are readily obtained through simulation. The simulator provides limited haptic feedback for improper catheter manipulations, such as advancing a catheter without a wire or exerting excessive sidewall pressure. It helps to improve a new fellow's efficiency in working with orthogonal and oblique two-dimensional fluoroscopic images. Multiple common anatomic variations are available. After 25 simulations and with the first few patient exposures, the fellow may return to the simulator to further refine the desired technique.

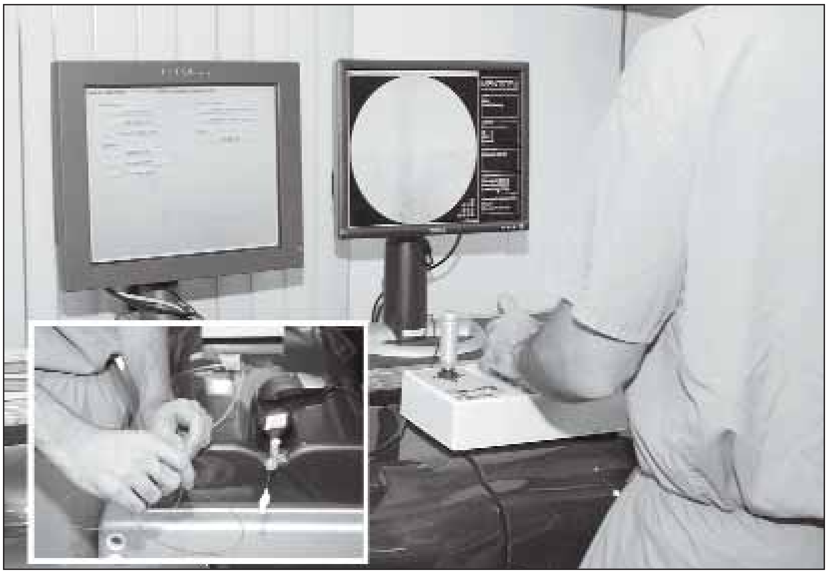

Figure 1. The Procedicus VIST system. With a series of three haptic devices and specialized computer hardware, this endovascular simulator models the appearance of real-time digital subtraction angiography with computer-generated images responsive to actual hands-on catheter manipulation. Software packages include simulation for carotid artery disease, intracranial aneurysms, as well as coronary, renal, and iliac pathological conditions.

NEUROENDOVASCULAR RESEARCH WITH VR TRAINING

Three trials have objectively evaluated the Procedicus VIST for the training of both novice and advanced operators in the technique of carotid stenting. In the first two studies, improvements in the procedure times were contrasted before and after formal simulator training.[1,4] Both studies demonstrated greater gains for novice operators than for advanced operators.

In the third study, endovascular skill acquisition with the VIST was tested in 20 experienced interventional cardiologists who were being trained in carotid stenting.[5] In this study, procedure time, fluoroscopy time, contrast volume, number of cine-loop recordings (static metrics), and composite catheter-handling errors (eg, vessel wall contact and improper technique) were recorded. Improvement in physician performance was shown, as well as internal consistency and test-retest reliability for the VIST.

Although these studies have tried to quantify the advantage of VR training on simulators, this is not always an easy task. In using the VR device, there are a multitude of complex visual and tactile manipulations that occur and become incorporated into the angiographer's armamentarium. Early on in the learning of angiography, many of these maneuvers become integrated as "reflex," and it is hard to document how that learning occurs except that the angiographer will describe feeling more "comfortable" performing the procedure in a human being after working on the simulator for several hours.

THE VIST SYSTEM

The Procedicus VIST has been used widely in carotid stent training and has been featured in the endovascular practical course at the last two annual meetings of the Congress of Neurological Surgeons. The system models the appearance of real-time digital subtraction angiography with computer-generated images responsive to actual hands-on catheter manipulation (Figure 1). It contains a series of three advanced haptic devices inside a life-sized human frame and includes realistic monitors, a control panel, Pentium IV processor, graphics card, and specialized software. The translational and rotational movements of real endovascular instruments are simultaneously recognized through the haptic interface. Other input comes through the control panel, foot switch, syringe injection, and indeflator. Output is seen as realistic angiographic images and may also be felt through resistance and torque applied to the catheters.

Software packages for the VIST system simulate carotid artery disease, intracranial aneurysm coiling, and intracranial stenting. Future improvements may include simulated use of new instrument prototypes and preprocedure rehearsal using patient-specific anatomy.

LIMITATIONS OF SIMULATOR TRAINING

The tactile feedback and action-response limitations of the VIST system make it most appropriate for novice operators. The one-to-one relationship of manipulating a catheter and visualizing change on the screen is excellent. Skills learned with VR require substantial further refinement during live procedures. Advanced procedures, such as microcatheter navigation, intracranial stent placement, and catheterization of intracranial aneurysms, are modeled with only rudimentary similarity to the clinical setting.

AVAILABILITY OF SIMULATOR TRAINING

Only recently has simulation-based training become generally accessible to universities, research centers, and hospitals.[8] Sophisticated simulators are suggested to cost up to $500,000.[9] Options to reduce such costs could include the use of portable systems shared by several institutions or the establishment of regional training centers.[8]

> " . . . Virtual reality simulation in neuroendovascular training is now ready for widespread use."

FUTURE CONCEPTS

One can envision a future simulator that would not only be used for development and training of techniques but also to practice treating difficult lesions. Once a diagnostic angiography was performed on a patient with a complicated neurovascular lesion, these data could be transferred to the computer simulator. The operator could then use a variety of techniques and devices in an attempt to cure the lesion. In this fashion, the simulator could be used as a "testing ground" for interventional procedures. The operator would then approach the patient for treatment armed with information as to whether a given approach would work anatomically and physiologically. In addition, having been through the physical manipulations to treat the lesion, the operator would be at an advantage when approaching the actual patient for treatment. Whether this type of strategy can be used to minimize risks and maximize outcomes has yet to be determined, but it certainly presents an exciting possibility.

CONCLUSION

Although limitations of tactile feedback continue, VR simulation in neuroendovascular training is now ready for widespread use. Systems such as the Procedicus VIST serve as a valuable training aid for new neurointerventional fellows and others who may be inexperienced with catheter technique. As the field advances, simulation of complication management and precise intracranial manipulations will continue to improve. ■

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Christopher S. Ogilvy, MD, is Professor of Neurosurgery, Harvard Medical School; and Attending Neurosurgeon and Director of the Brain Aneurysm/AVM Center and Cerebrovascular Surgery Unit, Massachusetts General Hospital, in Boston, Massachusetts. He has disclosed that he holds no financial interest in any product or manufacturer mentioned herein.

Rodney M. Samuelson, MD, is Clinical Assistant Instructor of Neurosurgery, Virginia Commonwealth University School of Medicine, in Richmond, Virginia. Bernard R. Bendok, MD, is Assistant Professor of Neurological Surgery and Radiology, Northwestern University–Feinberg School of Medicine, in Chicago, Illinois. Drs. Samuelson and Bendok each completed a neuroendovascular fellowship at the Department of Neurosurgery, School of Medicine and Biomedical Sciences, University at Buffalo, State University of New York, in Buffalo, New York. Dr. Samuelson has disclosed that he holds no financial interest in any product or manufacturer mentioned herein. Dr. Bendok has disclosed that he has received research funding from Cordis.

Kenneth V. Snyder, MD, PhD, is Clinical Assistant Instructor of Neurosurgery, School of Medicine and Biomedical Sciences, University at Buffalo, State University of New York, in Buffalo, New York. He is currently undertaking a rotation in the neuroendovascular training program in Buffalo. He has disclosed that he holds no financial interest in any product or manufacturer mentioned herein.

Gursant S. Atwal, BS, and Alexander M. Morrison are research assistants, Department of Neurosurgery, School of Medicine and Biomedical Sciences, University at Buffalo, State University of New York, in Buffalo, New York. They have disclosed that they hold no financial interest in any product or manufacturer mentioned herein.

Adnan H. Siddiqui, MD, PhD, is Assistant Professor of Neurosurgery and Radiology, School of Medicine and Biomedical Sciences, University at Buffalo, State University *of New York; and Codirector, Kaleida Stroke Service, Millard Fillmore Gates Hospital, Kaleida Health, in Buffalo, New York He has disclosed that he has received a research grant from the University at Buffalo and honoraria from Genentech, an American Association of Neurological Surgeons' course, and an Emergency Medicine Conference.*

L. Nelson Hopkins, MD, is Chairman and Professor of Neurosurgery, Professor of Radiology, and Director of the Toshiba Stroke Research Center, School of Medicine and Biomedical Sciences, University at Buffalo, State University of New York; and Chairman, Department of Neurosurgery; and Codirector, Kaleida Stroke Service, Millard Fillmore Gates Hospital, Kaleida Health, in Buffalo, New York. He has disclosed that he receives grant support from Boston Scientific, Cordis, and Micrus, and honoraria from Bard, Boston Scientific, and Cordis; has an ownership interest in AccessClosure, Boston Scientific, Micrus, and Square One, Inc.; and serves as a consultant to/member of the advisory board for Abbott, Bard, Boston Scientific, Cordis, and Micrus.

Elad I. Levy, MD, is Associate Professor of Neurosurgery and Radiology, School of Medicine and Biomedical Sciences, University at Buffalo, State University of New York; and Director, Neurointerventional Fellowship and Neurointerventional Catheterization Laboratory; and Codirector, Kaleida Stroke Service, Millard Fillmore Gates Hospital, Kaleida Health, in Buffalo, New York. He has disclosed that he receives grant support, other research support (devices), and honoraria from Boston Scientific; holds shares in Micrus Endovascular; receives grant support from ev3; serves as a consultant to Cordis Neurovascular and Micrus Endovascular; and receives fees for carotid stent training from Abbott Vascular and ev3. Dr. Levy may be reached at elevy@buffns.com.

1. Dayal R, Faries PL, Lin SC, et al. Computer simulation as a component of catheter-based training. J Vasc Surg. 2004;40:1112-1117.
2. Gallagher AG, Ritter EM, Champion H, et al. Virtual reality simulation for the operating room: proficiency-based training as a paradigm shift in surgical skills training. Ann Surg. 2005;241:364-372.
3. Grantcharov TP, Kristiansen VB, Bendix J, et al. Randomized clinical trial of virtual reality simulation for laparoscopic skills training. Br J Surg. 2004;91:146-150.
4. Hsu JH, Younan D, Pandalai S, et al. Use of computer simulation for determining endovascular skill levels in a carotid stenting model. J Vasc Surg. 2004;40:1118-1125.
5. Patel AD, Gallagher AG, Nicholson WJ, et al. Learning curves and reliability measures for virtual reality simulation in the performance assessment of carotid angiography. J Am Coll Cardiol. 2006;47:1796-1802.
6. Seymour NE, Gallagher AG, Roman SA, et al. Virtual reality training improves operating room performance: results of a randomized, double-blinded study. Ann Surg. 2002;236:458-464.
7. Connors JJ 3rd, Sacks D, Furlan AJ, et al. Training, competency, and credentialing standards for diagnostic cervicocerebral angiography, carotid stenting, and cerebrovascular intervention: a joint statement from the American Academy of Neurology, the American Association of Neurological Surgeons, the American Society of Interventional and Therapeutic Neuroradiology, the American Society of Neuroradiology, the Congress of Neurological Surgeons, the AANS/CNS Cerebrovascular Section, and the Society of Interventional Radiology. J Vasc Interv Radiol. 2004;15:1347-1356.
8. Dawson DL, Meyer J, Lee ES, et al. Training with simulation improves residents' endovascular procedure skills. J Vasc Surg. 2007;45:149-154.
9. Raths D. VR to OR. Can online learning and virtual reality simulators revolutionize medical training? June 2006. Available at: http://www.learningcircuits.org/2006/June/raths.htm. Accessed October 9, 2008.