Applying Simulation to Endovascular Medicine

How far has the technology progressed?

BY JOHN D. CARROLL, MD

The maxim, "See one, do one, teach one" can no longer be the only standard for medical education. Medical simulation has developed at an accelerating pace and now includes specialties from anesthesia to urology, and all points in between. High-fidelity simulators are in use throughout the US and the rest of the world, yet there is much work to be done in making simulation a fundamental part of endovascular medical practice, including use of metrics for assessment of competency. It is apparent that the simulation companies, industry, and societies involved are working toward this imperative.

DEVELOPMENT

In 1934, the US Army Air Corps purchased six flight simulators from the Link Company, and simulation started to become an accepted and vital part of the aviation world, making commercial flights safer for everyone.[1] The military has used simulators to train pilots, tank drivers, ship captains, and now doctors and medical personnel. The field of psychology is actively using various simulators to treat phobias such as the fear of driving, the fear of flying, and the fear of heights.[2] Simulation is becoming ubiquitous as a method for training and has begun to be used in high-stakes examinations. Locomotive drivers, airline pilots, and other transportation personnel hone life-saving skills when they step inside their respective simulators to qualify or requalify on a particular vehicle.

There is an amazing amount of diversity in the various simulation technologies. Simulators are accepted in aviation without validation because sending pilots up without simulation and comparing crash rates would put the public at risk. Thus, the efficacy of simulation in aviation is accepted on face validity.

Endovascular procedures lend themselves well to medical simulation because several physical and perceptual skills should be attained prior to live case mentoring. The ability to translate two-dimensional angiographic images into three-dimensional space is a skill better learned on a simulator than in real life. Rotational and translational manipulation of a catheter to navigate a vascular bed can be readily simulated and measured without any danger to a patient. Participants in an endovascular simulation can be presented serious adverse events that they may only encounter once or twice in their entire careers. Practicing the protocol of uncommon serious adverse events is stimulating and keeps the entire procedure fresh in the physician's mind and allows him or her to use the best practices and react quickly when needed.

> "High-fidelity simulators are used throughout the world, yet there is much to be done in making simulation a fundamental part of endovascular medical practice."

The learning curve for endovascular procedures has several major components. Initially, the primary operator, as well as the other team members are concerned with correctly executing the basic steps of the procedure, learning how to use the equipment and the devices, and "getting a general feel" for the tactile, visual, and clinical elements of a straightforward procedure in an average patient. This goal of simulation has been successfully attained for a variety of endovascular techniques in the last 5 years. The second portion of the learning curve is more complex and can best be described as the body of experience the perceptive operator will gather in the next several years from performing the procedure on numerous patients. This body of experience includes effectively dealing with complexities, including anatomic and clinical variations, complications, device quirks and malfunctions, and expert-level competency in the relevant cognitive, technical, and clinical skills. The Holy Grail for simulation will be the ability to efficiently and effectively transfer this body of "experience" from the operator or team performing the procedure for years to the operator or team just beginning.

In 1999, the American College of Cardiology brought simulation technology to its membership in its scientific session. The simulator had a relatively crude graphical representation of a simulated beating vascular tree into which contrast could be injected. This innovation in technology launched a revolution in endovascular simulation. In the last 5 years, great strides have been made in endovascular simulation, with a number of companies offering high-fidelity skills trainers, total procedure education systems, and team trainers.

The state of endovascular simulation in 2005 is far from what it was in 1999. Every simulation vendor offers multiple simulations in various vascular beds. One vendor has partnered with a major pacing device manufacturer and has created a library of pacemaker implantation simulations. Three vendors have partnered with various device manufacturers and created carotid simulators. Nearly all vendors have added renal and iliac simulations to their standard courseware. One vendor has created a library of right heart catheterization simulations. Left atrial appendage occlusion device simulation and patent foramen ovale closure simulation are both scheduled to be demonstrated at this year's TCT. The classical transseptal catheterization technique will soon be taught via simulation because many new electrophysiology procedures and structural heart disease interventions require this form of access to the left atrium. Almost anything that can be done with a catheter in any vascular bed has been simulated or is in development by at least one supplier of endovascular simulation.

MAJOR EVENTS

Hospitals Become Simulation Centers

During the last 5 years, there have been major advancements in the development of simulation technology that is evidenced by their actual use at major simulation centers. In Ohio, the Center for Medical Education and Innovation at Riverside Methodist Hospital features multidisciplinary simulations that hold broad appeal for the entire hospital staff. Brigham and Women Hospital's STRATUS program and center has preliminary data indicating a significant drop in central line infections that can be attributed to the mandatory training required for new fellows on central line placement simulators. In Washington, DC, the National Capital Area Simulation Center continues to grow and add new technology as it becomes available. At the University of Pittsburgh, one of the pioneers of medical simulation, a mobile unit is being used to train physicians and medical personnel with Laerdal Human Patient Simulators (Laerdal Medical Corp., Wappingers Falls, NY). There are simulation centers with more than one type of simulator at Harvard, St. Luke's/Texas Heart Institute, Stanford, University of Arizona, University of Michigan, University of California Davis, and other prestigious hospitals and educational facilities. A trend that has been seen in the last few years is a turn to simulation as an alternative to the Halstead mentoring method in not only teaching hospitals but also in commercial entities.

Collaboration

A number of the companies that develop endovascular simulators are collaborating with at least one major device company. These collaborations are allowing some of the funding to be shouldered by industry while the market continues to grow. Access to this type of simulation training is provided by manufacturers who purchase, maintain, and operate their own simulators, or through education service companies that provide specific simulation training for the manufacturer. As more simulation centers open around the country, the demand for simulators and simulation education will rise steadily, increasing profitability and promoting a healthy competition among these vendors.

Within the last 2 years, a major device manufacturer has substituted simulation training for proctored cases and thereby cut the risk to patients and meaningfully reduced the amount of time to deliver standardized, consistent training. Additionally, regulatory agencies have become more open to the use of simulators in several areas, particularly the high-risk area of carotid stenting. Other device manufacturers are clearly interested in the possibility of substituting simulation cases for proctored cases because it decreases the liability of using patients as training material and precludes scheduling problems, as the use of any particular device is not readily predictable. Recently, a device manufacturer had a simulation company develop a training protocol for their research trial investigators. That particular simulation will be demonstrated on stage this year at TCT.

Societal Involvement

The list of professional societies that are collaborating with simulation companies and incorporating simulation into their guidelines or curriculum is growing daily. Organizations including the ACC, SCAI, VIVA, SIR, and the vascular surgical societies have all in the past 3 years gone from testing the waters to actually using simulation as part of their meetings. The National Board of Medical Examiners has conducted a study that showed it is possible to discriminate between experts, intermediate, and novice practitioners performing right heart catheterization procedures. The Agency for Healthcare Research and Quality has funded a study[3] on patient safety utilizing a full-procedure cognitive simulation system that allows team training. The SCAI is in the process of establishing expert benchmarks on a simulation system so their members can perform the same simulation and compare themselves to an acknowledged group of experts. This program began with the creation of five unique "patient cases." The participant must treat the patient through diagnosis, selection of equipment, and actual intervention, including dealing with adverse events. The benchmark is established by analyzing the data from the expert panel members' treatment approach to identify trends at key decision points in the cases. The participants are then able to benchmark their treatment approaches on theses cases to the panel of experts. Metrics have been chosen for these benchmarks from the thousands of potential performance measurements captured by the simulation system, which demonstrates the analytical depth these technologies can offer. Recently the SCAI, SVMB, and SVS released a clinical competency statement on carotid artery stenting.[4] This report identifies three areas of competency: cognitive, technical, and clinical, and outlined the recommended minimum requirements for each area. One simulation company assembled many of the luminaries in carotid stenting and developed a curriculum that incorporates the key requirements of all three areas. The course contains didactic sessions and simulation sessions covering cognitive and technical aspects, and it also includes observation of live cases covering many clinical aspects.

Currently, the American Board of Internal Medicine is completing a pilot study testing the feasibility of using simulation as part of their certification or recertification process.[5] Preliminary results indicate the required level of discrimination between expert, midlevel, and novice can be detected by the simulator through its performance measurements. Using simulation in high-stakes examinations or certification is expected to become a reality in the near future.

METHODS

The approaches to development of endovascular simulation systems can be narrowed down to two methods. One is a haptics-centric procedural skills trainer that allows the users to practice and hone their psychomotor skills while using a medical device. Several studies have shown the effectiveness of this method in laparoscopic surgical simulators.[6]

The other method is a comprehensive simulation system that includes high-fidelity haptics to exercise the users' psychomotor skills while engaging them in an augmented reality simulation of the entire procedure. This approach exercises their cognitive abilities such as verbal ability, reasoning ability, deductive ability, and perceptual ability for a more complete learning experience. As the technology of personal computers continues to advance, the graphics these systems display will soon be indistinguishable from actual procedures and will be able to aggressively challenge even the most experienced practitioner.

ASSESSMENT

The learning curve for physicians resembles a steep ramp followed by a relatively flat line, indicating the maximum level of competency for that physician. The patients seen by that physician or fellow during the steep portion of the learning curve are particularly at risk. With the advent of various types of medical simulation, they can now practice through the steep portion of the learning curve, not taking up their mentor's time with simple questions and quickly learning the subtleties of technique. This method not only benefits the trainee but also the mentor who now has the time to educate the trainee at a more advanced level. Most importantly, the patient benefits because the inevitable mistakes made during the steep portion of the learning curve are not made during the real procedure.

Memory retention increases as a function of interaction, which makes simulation an ideal method of training, providing that suspension of disbelief can be attained and an adequate assessment method is included with the simulator.[7] In the field of laparoscopic surgical simulations, a great deal of research has been done regarding psychomotor measurements and the validation of their metrics.[8] These measurements have primarily focused on the clinician's physical dexterity skills. Today's endovascular simulators vary widely in their treatment of assessment or metrics. Some companies have chosen to focus metrics primarily on physical dexterity. A more expansive method is to identify and collect data on a large number of parameters encompassing technical, clinical, and cognitive skills, which allows for postsimulation performance assessment. Both of these methods have merit, and the second method is perhaps more forward-looking.

A very important area for assessment is the clinician's cognitive skills, including visual ability, numerical ability, reasoning ability, deductive ability, ability to see relationships, ability to remember, spatial ability, and perceptual ability.[9] One system measures these cognitive skills, as well as physical skills with success in its ability to discriminate between novices and experts. A National Board of Medical Examiners study showed discrimination, preliminary results of an American Board of Internal Medicine pilot study showed discrimination, and an ongoing study with the SCAI is based on the capability of this simulator to discriminate among different levels of competence. This method incorporates a comprehensive structure that collects more than

500 individual assessment data points ranging from "did the physician obtain informed consent" to determining that "a perforation occurred." This analytical methodology allows for multiple assessment points. An example of this would be correct positioning of an embolic protection device that includes apposition, appropriate landing zone, and correct deployment. The ability to use one or a combination of several performance parameters as the field of metrics in endovascular simulation matures will be a necessity.

Simulation companies are working with professional societies and device manufacturers to determine what is important to learn and to measure. For the device manufacturer, the measurement of the proper use of their device is generally the highest priority. For the clinician, knowing and delivering the proper treatment and familiarity with the procedure are paramount. With the recent collaborative publication of competency standards, an overall measure of competence including technical, clinical, and cognitive seems to be the primary focus.

CONCLUSION

Although much has been accomplished, and advancements in education and training using simulation are rapidly taking place, there is much work to be done in making simulation a fundamental part of endovascular medical practice, including use of metrics for assessment of competency. It is apparent that the simulation companies, industry, and societies involved are working toward this imperative. ■

John D. Carroll, MD, is Professor of Medicine; Director, Cardiac and Vascular Center; and Chief of Cardiology at the University of Colorado Hospital in Denver, Colorado. He has disclosed that he is part-time Medical Director of Medical Simulation Corporation, Denver, Colorado. Dr. Carroll may be reached at (303) 372-6555; john.carroll@uchsc.edu.

1. L3Communications. Link Simulation & Training: Setting the standard for over 75 years. Available at: http://www.link.com/history.html.
2. Thacker P. Fake worlds offer real medicine—virtual reality finding a role in treatment and training. JAMA. 2003;290:2107-2112.
3. Messenger JC, Rumsfeld JS, Carroll JD, et al. Enhancing patient safety during cardiac catheterization using simulation-based training. Top Health Information Management. 2002;23:82-93.
4. Rosenfield K, Cowley M, Jaff M, et al. SCAI/SVMB/SVS clinical competence statement on carotid stenting: training and credentialing for carotid stenting—multispecialty consensus recommendations, a report of the SCAI/SVMB/SVS writing committee to develop a clinical competence statement on carotid interventions. Catheterization and Cardiovasc Interv. 2005;64:1-11.
5. ABIM Web site. Assessment and Quality Improvement. Available at: http://www.abimfoundation.org/assessment.html. Accessed September 7, 2005.
6. Gallagher A, Satava R. Objective assessment of experience, junior and novice laparoscopic performance with virtual reality: learning curves and reliability measures. Surg Endosc. 2005;16:1746-1752.
7. Najjar LJ. Principles of educational multimedia user interface design. Human Factors. 1998;40:311-323.
8. Pearson A, Gallagher A, Rosser J, et al. Evaluation of structured and quantitative training methods for teaching intracorporeal knot tying. Surg Endosc. 2001;16:130-137.
9. Dunnette MD, ed. Handbook of Industrial and Organizational Psychology. Palo Alto, CA: Consulting Psychologists Press;1992:1-59.