Patient-Specific Anatomy in Interventional Vascular Simulation

Already an invaluable training tool, actual patient-specific modules will soon make simulators even more effective.

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The field of interventional vascular simulation (IVS) has recently evolved to the front of interventional training. High-tech simulators, based on complex haptics technology integrated with interactive imaging software, have been introduced to the area of percutaneous vascular interventions. Developed initially to simulate coronary anatomy and to virtually perform angiography and angioplasty, the field has rapidly evolved into other fields of vascular interventions, including carotid stenting, peripheral vascular interventions, PFO closure, and other emerging procedures.

In order to discuss patient-specific anatomy simulation, it is important to understand what simulation has been up until this time. Previously, most simulation anatomies have been modeled/based on actual patients whose anatomies are characteristic of commonly encountered subsets; data from a CT scans or MRIs are preprogrammed into a simulator, and vessels are reconstructed using that model. The modeling can be modified to adjust for certain anatomical variances (eg, thrombus, tortuosity, or calcification), but for the most part, it is specific to one random patient. Whether the case is carotid, renal, or iliac, the simulated patient is essentially generic.

PERFECT PRACTICE MAKES PERFECT

Manufacturers have now developed the next generation of simulated patients, which in addition to training interventionists on a certain procedure can also provide the ability to prepare for a specific case. The patient-specific anatomy model is one in which cross-sectional data, such as a CT scan or a CT angiography, can be programmed into a simulator, creating a model of a unique patient. Training on a patient-specific simulation provides the benefit of being able to anticipate unique problems, practice the procedure, and determine whether a specific technique or tool might be useful on a particular patient before the actual procedure. In essence, it allows a preview of the procedure before it is performed live.

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Although many experienced operators can anticipate possible problems, any of us will occasionally be surprised by what we encounter during a specific intervention. The hope is that patient-specific anatomy will provide a preprocedural planning upgrade that allows the interventionist to be even more prepared for the unanticipated difficulties (or lack thereof), which would be very useful, especially in difficult cases.

CAUSE AND EFFECT CAPABILITY

Current simulator technology includes complications and adverse reactions—even difficult anatomy—to which the operator must respond. Some simulators can be programmed so that if the interventionist inflates a balloon in the carotid, the blood pressure and pulse decrease; or if the operator chooses to approach a thrombotic lesion, it will embolize. Successful simulation involves not only the technical procedural considerations, but also the cognitive aspects of identifying emergent scenarios and choosing the appropriate therapeutic response.

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Simulation can also allow the development and recording of certain metrics—measurements of response times, the choice of equipment, the choice of medication, movement of wires and catheters—the elements in reflections of decision making that can be quantified and "graded" against an average interventionist.

IMPACT ON TRAINING

There have been published studies looking at the ability of an operator trained on a simulator versus an operator trained solely by traditional methods in the endoscopic arena. In these studies, operators who were trained on the simulator were shown to achieve a lower level of errors more quickly. Applying patient-specific training modules should further improve this learning curve, as they expand the number of cases in the simulator "library" with larger variety of possible patient scenarios a trainee can practice upon.

In time, it is anticipated that credentialing and certification in the surgical and interventional specialties will include some element of simulation. In fact, the current FDA-approved carotid stent certification includes a simulated experience. Both Cordis (a Johnson & Johnson company, Miami, FL) and Guidant (Indianapolis, IN) have implemented hands-on training on a simulator as part of their training of interventional cardiologists who want to use their carotid stenting system, which includes new filter-based distal protection and a self-expanding stent. This training was part of their application for FDA approval and was implemented in the training of interventionists who applied to be included as operators/investigators in the post-surveillance studies. The simulator-based training includes a few hours of performing "cases" at increasing levels of difficulty, enabling the trainee to practice the steps of the procedure, to practice his or her response to hemodynamic changes, and to practice the deployment of the filter and stent.

The technology of IVS has progressed rapidly and is in constant development. New technical and conceptual features are being added in upcoming models, and much emphasis is being placed on automatic skill evaluation. The idea is to use IVS as a virtual-reality examination tool. The examinee is asked to do interventional cases on the simulator, which will automatically score performance (technical as well as response to emerging events). Parameters that can be evaluated include the duration of various segments of the procedure, selection of the appropriate devices, selection of the correct sizes of balloons and stents, appropriate anticoagulation and other medications, and handling of emerging problems such as complications. In the foreseeable future, simulators and their skill assessment technology will be used for examination of fellows as part of the board examination, and for assessment of the skills of interventionists before performing a newly learned procedure or use of new devices.

Validation studies are being done now on various simulators to validate the automatic simulator-generated scoring system. At the end of this development, IVS systems will be able to discriminate between novice and expert operators, and hopefully establish a threshold at which an operator can be certified to do a safe and successful procedure. Applying the patient-specific anatomy technology to this concept is ideal. It will allow indefinite number of virtual cases based on real patients, with real-world challenges.

SUMMARY

Patient-specific anatomy is a new emerging component of IVS that will turn the library of virtual cases from generic cases to indefinite number of training cases and procedures. In addition, the option to practice on the specific anatomy of a real patient will enable operators to define the appropriate devices for the specific patient—before the actual intervention. There is no doubt that such a strategy can improve the safety and success of the procedure. Combined with the current technology and software improvements, including skill assessment, patient-specific anatomy brings the field of IVS to new heights. The new applications derived from patient-specific anatomy IVS may increase the demand for the placement of simulators in a larger number of institutions. ■

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