Simulation as a Training Tool for Vascular Interventional Radiology

- A high-fidelity physics-based simulator for use in vascular interventional radiology (IR), interventional cardiology, and vascular surgery offers the ability to:
  - Insert actual guidewires and catheters with realistic haptic feedback
  - View simulated fluoroscopic images that show two-dimensional (2D) displays of three-dimensional (3D) anatomy
  - Change the angle of "fluoroscopic" views using controls at the side of the "fluoroscopic table"
  - "Inject" contrast agents
  - Training modules are available for a wide variety of vascular IR procedures with different levels of complexity and can simulate errors resulting in patient injury
  - Simulation is being introduced as part of the curriculum for training radiology residents

The skills required for vascular interventional radiology (IR) include knowledge of vascular pathophysiology and diagnostic tests, interpretation of complex 3D anatomy from 2D displays, precise hand-eye coordination during interventions, and knowledge of the required techniques for many different procedures. Traditionally, these skills have been developed through a one-on-one interaction between the physician-mentor and the trainee. However, such training is constrained by the availability of patients with specific conditions and the need to minimize procedure time, especially in morbidly ill patients, to avoid unnecessary complications. These considerations mean that the trainee has limited exposure to challenging procedures and complex patients. Moreover, there is no objective assessment of the skills acquired by trainees; rather, a log of procedures is used to document the number of cases performed during training.

Realistic simulation systems can enhance training by presenting a larger volume of specific diseases to the trainee and reducing case-mix inequalities caused by unequal presence of patients with specific diseases. Simulation allows repetitive practice to develop the complex skills required in both straightforward and difficult cases without the risk of causing harm to a real patient. Procedures can be repeated as often as needed. Therefore, trainees can gain experience in performing a wide range of procedures over a relatively short period of time, or they can focus on perfecting difficult maneuvers in complex cases until performance errors are eliminated.

While the notion that a trainee learns quickly by performing procedures on patients under the direct supervision of an expert and all errors are caught before any harm is done may be accurate most of the time, it may not always be true. Flight training for pilots has long depended on simulation; the medical profession may also benefit given the potential to reduce medical errors and increase patient safety.
The Vascular IR Simulation System

The simulation system (Figure 1) recently installed at Mass General allows physicians to use actual catheters and guidewires, which they insert and manipulate while getting real-time feedback via a haptic device and a visual "fluoroscopic" display of anatomy on a video monitor. The angle of anatomic view is controlled at the tables by a second operator, either a technologist, a resident, or a fellow. Another monitor displays physiological values, such as heart rate, rhythm, and blood pressure.

Tactile sensory feedback is provided by a haptic interface that tracks catheter translation and rotation with independently controlled servomotors that produce force and torque resistance. The proximal catheter force and torque is calculated from motion measurements and other data from a physical model developed for the system. The haptic interface also detects injection of "contrast" when the plunger of a syringe is depressed.

The fluoroscopic monitor shows an accurate, detailed anatomic display derived from three-dimensional models and rendered into real-time two-dimensional simulated images that can be seen from any angle, as well as the position of a guidewire, catheter, angioplasty devices and stents, and injected contrast material. The models also incorporate physiological parameters, such as cardiac rhythm and rate and blood flow. The result is a highly realistic display that corresponds to that seen when treating a patient. All displays and interactions are controlled by mathematically-based models derived from principles in physics, computed in real-time by the system's internal processors.

The simulator includes a wide variety of training modules, ranging from aortic stent graft placement to uterine fibroid embolization. Each procedure has varying degrees of difficulty that, for example, can simulate straight or tortuous vessels, vessel narrowing due to atherosclerosis, and variations in human anatomy. The system detects
user errors but does not halt procedures. Instead, it records errors and displays physiological consequences, such as reduced blood pressure or elevated heart rate. By simulating complications, the system provides the trainee with an opportunity to learn how to handle them before confronting them in a real-life situation.

When a complication occurs in a simulated scenario, the case can be "suspended" in time and a discussion of causes and corrections can occur, providing immediate feedback to the trainee. Trainees can learn from their mistakes, "undo" them, and repeat the procedure. The system also allows them to skip forward in time to focus on the most challenging part of a procedure rather than performing it from the beginning. Therefore, the trainee can practice freely until she is comfortable with the procedure. It is also possible to pause the x-ray image rendering process and view a simulated moment in time from many perspectives to learn the best views for each stage of the procedure.

Resident Training

The vascular IR simulation system will become part of the curriculum for second-year radiology residents at Mass General in fall 2013. The system has been installed in an unused operating room in the White Building on the hospital’s main campus in Boston, providing a realistic setting for training. Mentors will either guide or observe trainees as needed, allowing them to learn at their own pace. When deemed proficient by a faculty mentor, residents will continue to the angiography suite for their first patient encounters.

Further Information

For more information about simulation training for vascular IR, please contact Steven Dawson, MD, Interventional Radiology, Massachusetts General Hospital, at 617-726-8396.

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References


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