Researchers devise simulators to unmask arterial blockages

BY ANDY SHAW

Phantoms first appeared on the medical scene in the 1920s when crude wax blocks and water tanks substituted for human tissue in X-ray experiments.

Today, highly sophisticated 'medical phantoms' reproduce body parts or even the whole body for use in a wide range of research, testing, calibrating, teaching, and more recently, therapeutic imaging applications.

Phantoms can be actual physical models of the head or the abdomen, for instance; or they can be programmable 'black boxes' containing plastics or gels that mimic human tissue, including diseased arteries; or they can be computer-generated, virtual phantoms – all of which help radiologists better understand through simulation what they see when they expose real humans to real radiation.

At the Centre Hospitalier de l'Université de Montréal (CHUM), research engineer Dr. Guy Cloutier directs the works of the Laboratory of Biorheology and Medical Ultrasonics, which develops better phantoms for use with ultrasound, CT, and MR imaging.

Most recently, Dr. Cloutier's lab has developed a new surgical stent designed to be particularly compatible with cardiovascular MR imaging. Its design is now in the hands of CHUM's technology transfer office and ready for commercialization after much research and development at CHUM.

"What we set out to show was how well the stent reduces the artifacts that can obscure MR images," explains Dr. Cloutier. "When you put a stent into an artery, in 20 to 30 percent of the cases, there will be a re-stenosis. In other words, the vessel will get blocked up again inside the stent. That creates a shielding effect that hides the blockage from CT or MR examination and therefore prevents proper diagnosis. So they asked us to evaluate this using a phantom. Of course, you couldn't do this with a real patient unless you went in and cut the artery open."

Using an experimental phantom blackbox that draws on a database of images and analyses them with algorithms, Dr. Cloutier can identify the imaging artifact in CT or MR exams that's shielding the re-stenosis from view and in effect he can peer through it, exposing the blockage itself.

"The patent that's at the base of the system relates to the use of markers that are visible in all imaging modalities. They give you the means to combine the modalities in multiple ways in order to get the clearest picture possible of what you are looking at."

CHUM's Dr. Cloutier has devised phantoms that can improve the images produced by CTs and MRs.

In other words, clinicians using the new image-mixing phantom will be able to combine an ultrasound with a CT and an MR image by superimposing the markers on one image over the same markers on the other images – and then re-construct from the three lined-up pictures a single 3D image of the target vessel.

"The box contains material that mimics human tissue when looked at by either ultrasound, CT or MR," explains Dr. Cloutier. "And it took a lot of research to find the right material."

To get it so a blockage looks right to a radiologist using the box in any modality, Dr. Cloutier and his researchers had to calibrate the acoustic impedance and the X-ray absorption, among a lot of other qualities of the candidate materials for inside the box.

"But now that we've got it right, you can even plug the box into a pump, for instance, and measure the flow of a blood substitute through the phantom 3D construction of the re-stenosis and stent in the artery," explains Dr. Cloutier.

The boxes and their software produce high-resolution models of the geometry of the vessel, its sclerosis, stents, or catheters. The computer controlled flow pump passes the blood substitute through the model's plastic or gel imitation tissue and

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measures its velocity – to help clinicians analyze what they are seeing, or maybe not seeing – in actual MRI, CT, or ultrasound examinations of the blocked or repaired vessel.

In short, phantoms simulate both the blood flow and the pathology of the suspect vessel. The result is there are many applications for phantoms.

"For example, because you are creating models they can be used to plan future interventional procedures and they can be used as teaching tools," says Dr. Cloutier. "Manufacturers also use them to test and calibrate their devices. Similarly, the medical physics departments in hospitals use them to check the calibration of the hospital's own imaging equipment.

"But also one of their jobs is to advise what the best products on the market are for their particular institution's needs. The department can use phantoms to assess the accuracy of a prospective purchase. That's pretty important to know when you are buying a piece of imaging equipment that may cost $5 million."

Under development currently is a large phantom black box in Dr. Cloutier's lab weighing in at a hefty 100 pounds that can mimic what's going on, bloodflow-wise, throughout the entire human thorax. It is meant to keep in step with diagnostic imaging's progress towards larger area and whole body imaging.

Shelley Medical Imaging Technologies, close to London, Ontario, has already commercialized several imaging phantom systems, including an aneurysm phantom bought from Dr. Cloutier's Biorheology and Medical Ultrasonics Laboratory.

Shelley specializes in highly accurate blood flow and vascular simulation machines and software for diagnostic medical imaging. Its phantom products include pump simulators, vascular models, and blood mimicking fluids for use in a range of applications including MRI, CT, ultrasound, endovascular, and angiographic imaging.

Shelley's world-wide customers include over 100 hospitals, universities, research institutes, regulators, and manufacturers. Among the notables are the BC Children's Hospital, Toronto's Sunnybrook Health Sciences, Stanford University, Duke University, Britain's Kings College Hospital, the Mayo Clinic, the U.S. National Institutes of Health, the Food and Drug Administration (FDA), the medical wings of GE, Philips, and Siemens – and quite naturally the neighbouring Imaging Research Laboratories at the Robarts Research Institute.

Phantoms can be used to plan interventional procedures and also as teaching tools, notes Dr. Cloutier.

Dr. Cloutier is also proud of a one-year licensing option agreement his lab signed in January with Boston Scientific. It's connected with a phantom application that will improve intravascular ultrasound examinations of the femoral artery. With 20-percent funding from Boston Scientific and the remainder from the Quebec Government, Dr. Cloutier will validate the system as the next step towards its commercialization.

"Because the femoral artery is larger than coronary arteries, where most imaging development has gone on, we use a lower-powered transducer (20 MHz) so that we get less artifacts being reflected back from the blood and get a clearer picture than you would using the higher powered (40 MHz) technology for coronary arteries," explains Dr. Cloutier.

Also, Dr. Cloutier's lab has just concluded a clinical study of 45 stroke victims testing the ability of phantom technology to measure the elasticity of the carotid artery as a means of predicting strokes. He and his staff are currently writing up a scientific paper on the results for international publication.

And most recently, Dr. Cloutier reports, two major pharmaceutical companies have been discussing using phantom black boxes to help design and initially test new drugs. It's a method that could possibly save the lengthy drug development process both years and millions.