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Mark Fillinger developed software that constructs 3D color images of blood vessels from black-and-white CT scans.

Hard data about software for vascular imaging

The difference between a vintage black-and-white film and a 3D IMAX movie may be derided by nostalgia buffs as mere bells and whistles. But there's no denying the visual detail that 3D offers. And visual wizardry is not confined to Hollywood. A 3D technology pioneered at Dartmouth is now giving vascular surgeons a view of places that before they could only imagine—and, in the process, helping them extend lives.

The largest blood vessel in the body, the aorta, runs from the chest to the abdomen. A bulge called an aneurysm can form at a weak section of the abdominal aorta. If it grows too large, the bulge can burst. Ruptured abdominal aortic aneurysms (AAAs) are a leading cause of death in the U.S. Fixing them before they burst is critical, for once rupture occurs death is almost certain.

Graft: A key step in deciding whether to treat an AAA, and how, is getting an accurate picture of it. Some aneurysms require an open surgical procedure, in which a large incision is made in the abdominal wall; then a graft, or fabric tube, is inserted to replace the weak spot. But many AAAs can be fixed using a less invasive procedure called endovascular repair, in which the graft material is introduced through a tiny incision in the groin and fed up the aorta by a guide wire. "We assemble it like a ship in a bottle," explains vascular surgeon Mark Fillinger, M.D. But getting an accurate view of the AAA is essential, since unlike an open repair—in which the surgeon can just eye the aneurysm and cut a graft to length—a surgeon doing an endovascular repair must rely on preoperative images to make graft measurements. There's little room for error.

Dye: Traditionally, imaging of AAAs has been done with an arteriogram—an x-ray procedure that creates a 2-dimensional, black-and-white picture by introducing dye into the artery. There's a certain amount of professional guesswork in using a 2D arteriogram to judge the dimensions of a graft.

In 1994, Fillinger attended a talk by Juan Carlos Parodi, M.D., a pioneer in endovascular aneurysm repair. After pondering the imaging challenge, Fillinger—whose undergraduate major was mechanical engineering—began working with Dartmouth engineers to develop graphics software able to build a 3D picture of an AAA from 2D CT scans, then simulate the application of a graft. "We can alter the path on the computer and say, 'What if it takes a shorter path? What if it takes a longer path? What if we use this graft or that graft?'" says Fillinger, "before we even decide if the patient is a candidate."

While continuing to use conventional arteriograms, Fillinger began imaging his patients in 3D color as well. Blood flow appeared in red, noncalcified plaque in yellow, and calcified plaque in white. "What we found was that in the cases where the arteriogram and the 3D reconstruction deviated from each other, it was the 3D reconstruction that was the more accurate," he says.

Even so, at his first major presentation of data, in 1996 at the European Society for Vascular Surgery, his work was met with skepticism. One of the few people who showed interest was Parodi. "He could see it had a lot of promise," says Fillinger. The same year, the Food and Drug Administration approved using 3D imaging instead of, not just in addition to, conventional techniques.

Irony: In 1998, DHMC surgeons became the first in the world to stop using preoperative arteriograms, Fillinger says. "The irony is that the preoperative workup had been more invasive for the less invasive endovascular procedure. With the 3D reconstruction, we make the preop workup and the repair itself less invasive, use less dye, less radiation, and it's less expensive. No downside."

A study in the *Journal of Vascular Surgery*, comparing 3D results at DHMC to arteriograms at other large institutions, showed the 3D approach to be equal or better. It reported that 95% of Dartmouth grafts did not require secondary intervention after surgery, compared to 75% of grafts in a large European vascular registry called EUROSTAR. And graft leaks were dramatically reduced; only 6% of Dartmouth grafts leaked, versus 24% of EUROSTAR grafts.

Yet surgical methodology changes slowly. Whether because of habit, nostalgia, or financial issues, arteriograms continue to be widely used. Even Fillinger wasn't sure the 3D technology would have value with open surgical repair. "We quickly found out that this shows us things that I could not interpret out of those 2-dimensional images. You can tell people that, but until somebody actually uses it, and things are revealed to them that they didn't see from the original images, they don't believe it."

Lee McDavid