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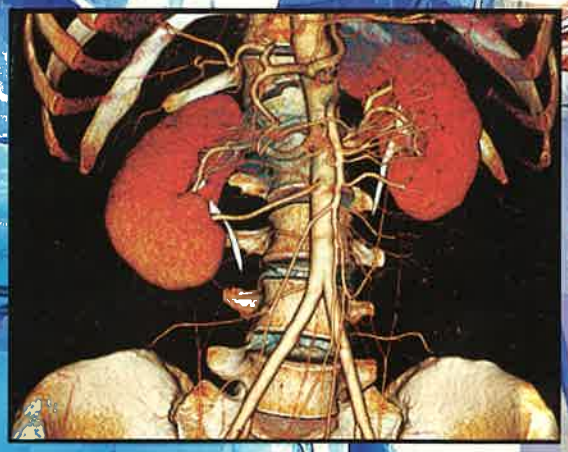

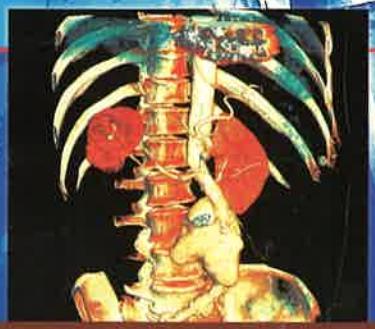

Operation Imaging

Radiology is Changing The Face of Surgery

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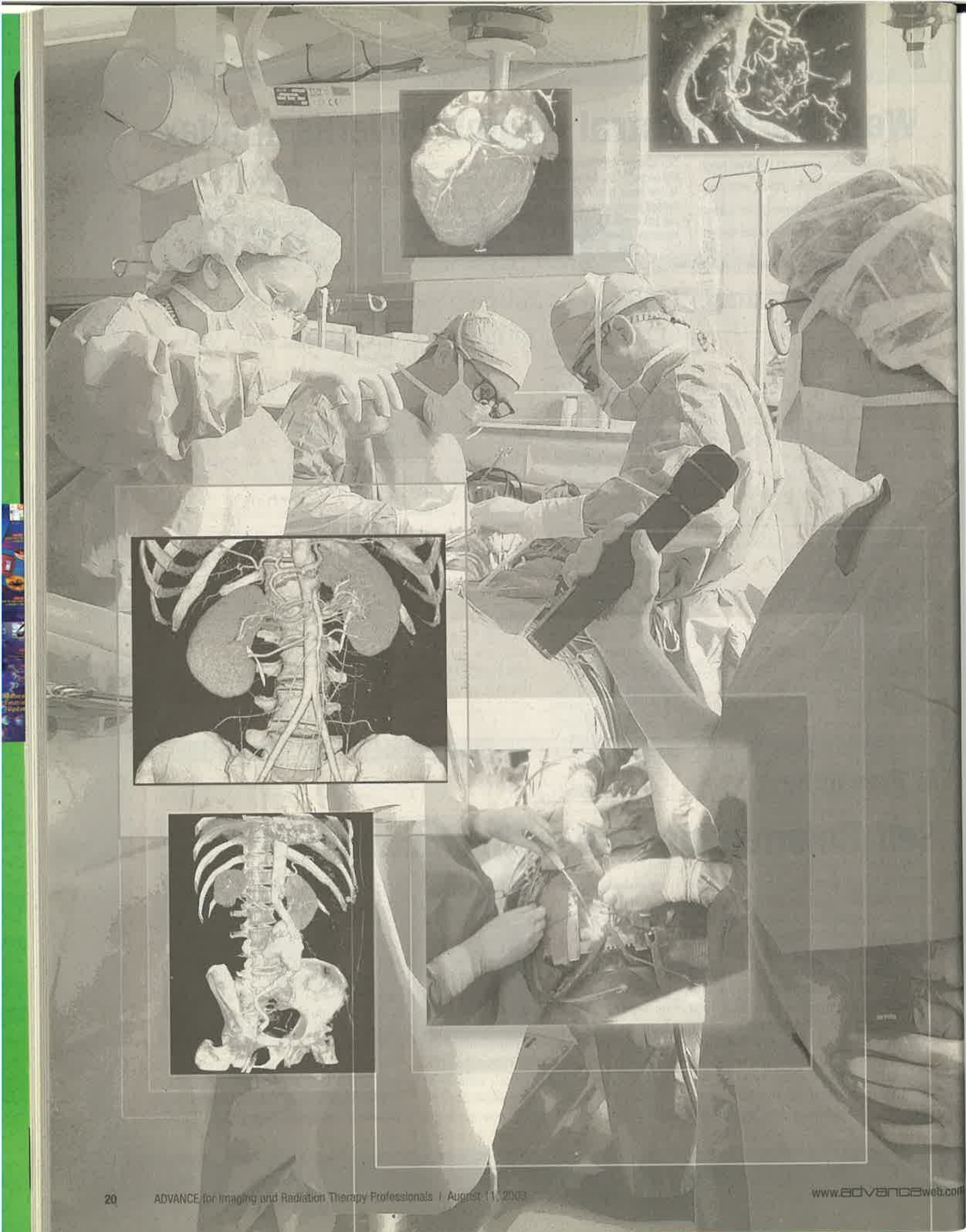


operation IMAGING

Three-dimensional MR, CT and ultrasound are beginning to change the face of surgery | BY SARAH LONG AND LAURIE STEWART

With the advent of minimally invasive surgery, image guidance has become vital to many procedures in the operating room.

Currently most surgical imaging consists of traditional CT and MR axial slices, as well as ultrasound images, taken prior to surgery. The surgeon then mentally reconstructs the images in deciding how best to approach a given procedure. Fluoroscopy and ultrasound are typically used during surgery to monitor the progress of the procedure, but MR and CT are increasingly being used by surgeons to take axial images intermittently during surgery.

Helpful as they are, however, flat images don't always tell the whole story about the relationship of anatomical structures. To improve surgical planning and procedures, some surgeons are turning to 3D imaging with MR, CT and ultrasound. The more lifelike and maneuverable images offered by 3D enable surgeons to view the patient's anatomy from multiple angles and better plan the surgical approach to difficult structures. Soon, surgeons may be practicing various surgical approaches using "virtual patients" constructed from these images. And that's not all: Since anatomy can shift during surgical procedures, surgeons may in the not-too-distant future be relying on 3D imaging for guidance during actual procedures, lifting image-guided surgery to a whole new plane.

That said, here's a quick look at where things stand now in surgical imaging, as well as what's coming over the horizon.

Growing attraction for 3D planning

One thing is crucial in surgical planning: clear, crisp images that give precise detail about what lies beneath the skin at the proposed surgical site. To achieve this end, many experts are singing the praises of 3D—as in 3D MR, 3D computed tomography and 3D ultrasound.

At Temple University Hospital in Philadelphia, 3D MR imaging is most commonly used to map blood vessels before aortic graft repair and to plan other vascular procedures, including aneurysm treatment, said Gary Cohen, MD, a Temple radiologist.

"For instance, we view the image from every angle so we can get a sense for the length of the aneurysm, the structures related to it, its front and back, and we can determine what needs to be done to it," Dr. Cohen said, adding that in conjunction with 3D CT, 3D MR is also used to map tumors for ablation and removal.

The advent of stronger magnets, such as the 3T magnets making their way into the marketplace, is also making for sharper images and more accurate presurgical planning.

"With 3T, we will get much better resolution in detail so that we can improve the resolution and contrast for procedures," said Paul Wang, MD, of Oregon Health and Science University (OHSU), Portland. "The expectation is we can get much higher resolution and higher detail for in terms of localization they are putting into the patient."

The OHSU team began employing a Philips Intera 3T scanner in January, soon resulting in a skip factor very close to zero, said OHSU's William Woodward, PhD. Dr. Wang said another benefit of the 3T machines is that they produce even thinner slices than the 2D machines.

"Concise 3D images give you higher resolution, thinner slices and a higher signal-to-noise ratio," Dr. Woodward agreed.

Meanwhile, three-dimensional CT is also delivering clear- ▷

ADVANCE PHOTO BY JEFFREY LEESER; PHOTOILLUSTRATION BY TOM CENTOLA

er scans. Faster scan times and multi-slice machines provide more detail in less time than single-slice scanners, giving surgeons the pictures necessary for performing successful surgery.

"The real-time capability of looking through these images lets [surgeons] appreciate the relationship between the structures they are interested in," said Frederick Long, MD, section chief of Body CT and MR at Children's Hospital Columbus, Ohio.

Dr. Long works with pediatric patients undergoing CT angiograms, using controlled ventilation, a method that results in nearly motionless images of children and infants. The technique spares children the more invasive traditional angiogram.

"We can get very gorgeous images of very fine structures," Dr. Long said. "The contrast resolution is superior to MRI. What we've done is we've saved the kids the additional study of an angiogram, and are giving the physicians more information on how to plan their course. Essentially, there are questions they need to know before they operate on congenital heart patients. By doing the 3D study, you can see everything, and they will know whether or not it is possible to do a particular procedure."

Ultrasound

Ultrasound's ability to offer interactive visualization of anatomy in real time makes it a valuable planning tool for surgeons, said Daniel F. Leotta, PhD, research assistant professor in the department of surgery, vascular division, at the University of Washington, Seattle.

Knowing that accurate measurements of abdominal aortic aneurysms (AAA) are required for surgical planning, Dr. Leotta and his team from the University of Washington examined the feasibility of using a 3D ultrasound imaging system to derive such measurements. The results were published in the April 2001 issue of the *Journal of Vascular Surgery*.[1]

In the study, the team used a 3D ultrasound imaging system to scan a normal aorta, a small AAA and an AAA repaired by an endovascular stent graft. They generated a 3D surface reconstruction from a sequence of 2D ultrasound images and took various diameter and distance measurements.

The results showed that creating a 3D surface reconstruction from ultrasound images is a promising method for quantitatively characterizing the geometry of AAAs both before and after endovascular repair, according to the researchers.

"For screening and monitoring [ultrasound is] good because it's relatively inexpensive and safe for the patient so if you want to follow somebody over time, the cost, time and risks to the patient are very low," Dr. Leotta said.

In the operating room

With a few exceptions, 3D medical imaging is taking its time showing up in the actual surgical suite. Some facilities have integrated MR into the operating room, allowing images to guide surgeons during surgical procedures. Magnets are either immobile, requiring that the patient be rolled into the scanner, or mobile, moving along ceiling tracks to the patient.

Bringing MR into the operating suite, however, presents the challenge of removing all ferromagnetic materials from the room to ensure safety of the patient and medical staff. MR-compatible anesthetic equipment and carbon, plastic or titanium surgical tools must be used.

However, with the proper precautions, MR used during surgery provides high-resolution soft tissue imaging that gives surgeons a clear view that would otherwise be unavailable during such surgical procedures as brain tumor removal. Real-time MR scans are giving surgeons at some facilities a clear view of brain tumors and showing them where tumor tissue ends and normal tissue begins.

But, Dr. Cohen said, the easiest and most cost-effective real-time 3D imaging procedure for the surgical suite is ultrasound.

"The least expensive modality, and perhaps the one that can be used most readily, is 3D ultrasound," he said. "It can be readily applied and would be the first and foremost to move from the diagnostic suite to the OR because of cost considerations."

The use of 3D ultrasound during surgery is still very much in the research phase of development, but the modality's portability and low cost could pave the way for a smooth transition from the diagnostic suite to the operating room. Some researchers contend that 3D ultrasound has the potential to help guide needles and catheters during minimally invasive surgeries, although it is not a commonplac practice at this point.

Although a 3D ultrasound imagin application dedicated solely to surgery h not been developed enough to discuss se ously, Siemens Medical Systems, Malver Pa., anticipates that future 4D transduce will come equipped with biopsy guides t navigate biopsy needles, according to company representative.

"Ultrasound has real potential for thin like aneurysms to show you where yo devices are during your surgeries an again, it's an unobtrusive piece of instru mentation ... that can really help out," D Leotta said.

Computer-based navigation system based on pre-operative MR or CT imag help surgeons locate areas of interest wit high precision in the planning proce prior to surgery. However, these tools hav limited value for guidance once organ shift during surgery. Potentially, high qua ity, intraoperative 3D ultrasound coul help surgeons navigate surgical tools base on images representing the patient's cu rent anatomy.

"You do your plan in 3D beforehand an then if you go in there and move organ around, your registration with your pr operative scans is no longer valid," D Leotta said. "So if you can do your 3D ultra sounds during your studies, you actuall have real information about where your o gans are. I think that's the biggest plus—tha you can actually do this and see real tim changes when you introduce a probe."

Ultrasound also would allow surgeon to measure blood flow and monito changes in blood vessels.

Researchers from SINTEF Unime Ultrasound and the University Hospital o Trondheim, both in Trondheim, Norwa explored 3D ultrasound-based navigation i abdominal interventions and neurosurgery.

In an article published in the June 2 issue of *Cardiovascular Interventiona Radiology*, the SINTEF Unimed research ers evaluated the use of preoperative imag data in a 3D ultrasound-based navigatio system specially designed for minimall invasive abdominal surgery.[2]

The patients were imaged first by spira CT followed by 3D ultrasound scanning The researchers then compared correspon ding slices from 3D ultrasound and C

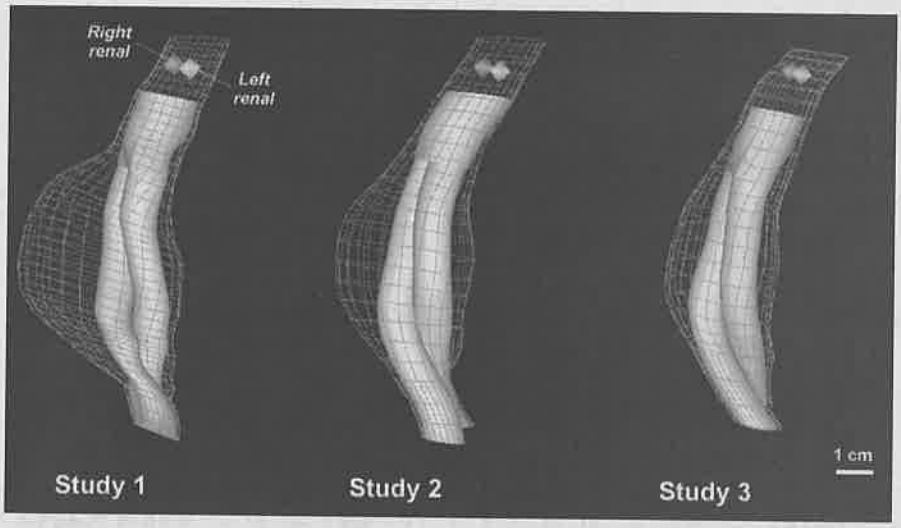
volumes using external fiducial markers and intraoperative 3D ultrasound as a measure of the true positioning of anatomic landmarks inside the body.

The mean registration accuracy on the surface was found to be 7.1 millimeters, but increased to 13 millimeters for specific landmarks inside the body. CT and ultrasound gave supplementary information of surrounding structures and position of the patient's anatomy, leading the team to determine that preoperative CT in combination with 3D ultrasound might be helpful for guiding minimal invasive abdominal interventions.

The team from the University Hospital of Trondheim summarized four years of clinical experience in the use of intraoperative 3D ultrasound integrated into neuronavigation for guidance in brain tumor resection in the April 2002 issue of *Neurosurgery*.[3]

Intraoperative 3D ultrasound is a good solution to the problem of brain shift in neuronavigation because it provides an updated and more accurate map of the patient's true anatomy in all phases of the operation, the researchers determined.

"Ultrasound makes it possible to follow the progression of the operation, and it improves the radicality of tumor resection by detecting tumor tissue that would remain if the imaging technology had not been used," the authors wrote. "Integration of 3D ultrasound with navigation technology solves the orientation problem experienced previously with two-dimensional ultrasound in neurosurgery."



Serial study of an AAA repaired by an endovascular graft. The 3D reconstructions show both the aneurysm (outer mesh) and the graft (inner surface). The studies were performed 1) 2 weeks, 2) 6 months, and 3) 1 year after graft placement. Diamond markers show the origin of the renal arteries. *(photo/courtesy Daniel F. Leotta, PhD)*

Further research

Three-dimensional ultrasound imaging still has challenges to overcome before it becomes commonplace in surgical applications. The image quality of ultrasound is much lower than other modalities like MR and CT, and there's a learning curve involved in reading ultrasound exams.

"But more places can afford an ultrasound machine so there's more availability that way," Dr. Leotta said. "It's less obtrusive during an exam, and there's no danger to the patient because there is no radiation. You can do it without contrast so there's not really a penalty to having it in the [operating room]."

Single-plane ultrasounds can be difficult to interpret for the inexperienced user, but imaging in three dimensions offers a larger perspective, Dr. Leotta said.

"A single plane in an ultrasound can be misleading unless you're the person who's holding the probe," he said. "It's hard to tell exactly what you're looking at because different views can look similar."

For example, in a single-plane image, a blood vessel appears as a circle, but a 3D reconstruction shows the whole vascular tree and provides a clearer picture of where things are located anatomically.

"So guidance-wise it's a huge advantage, especially for a team of people," Dr. Leotta said. "If you want to convey the information to someone who's not ... reading an ultrasound, they can relate to the [3D image] much better."

Researchers continue to focus their attention on using ultrasound for minimally invasive treatment of tumors and guiding probes and catheters during surgery, Dr. Leotta said. Three-dimensional ultrasound can be used not only as a navigation tool during surgery but for assessment afterwards to monitor, for example, changes in tumors.

"I think using 3D ultrasound in real time to guide minimally invasive surgeries is a big area," Dr. Leotta said. "These 3D reconstructions from the MR and CT are also extremely useful in telling you how to do the surgeries, how to approach things. But it's still going to take some time to develop. I wouldn't call it commonplace, but I think 3D imaging can make a big impact in surgery." ■

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