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DIAGNOSTIC IMAGING

3D CT bolsters radiologist, clinician relations

Fostering Communication

by Deborah R. Dakins

Once 3D CT was perceived as a frivolous add-on to impress referring physicians. Now it creates newly collaborative relationships between radiologists and clinicians. In applications that range from aortic aneurysm grafts to routine review of abdominal scans in cancer evaluation, 3D CT allows radiologists to communicate more critical information than ever before.

In practice, much of this collaboration is informal, the result of confabs between radiologists and surgeons or other specialists. Most of these occur in the radiology suite during huddles around the 3D workstation. But such cooperative care is expected to take off as 3D transitions from stand-alone stations to robust networks capable of distributing data-rich displays to PCs.

"When it is made easy for clinicians to manipulate and interact with 3D data, they're very excited about it," said Dr. Geoffrey Rubin, chief of cardiovascular imaging at Stanford University.

Clinicians have been quick to see 3D's value. Radiologists convey findings faster and in a more dynamic fashion than in 2D mode. Volume rendering affords the ability to extrapolate key findings from 1000-slice data sets and demonstrate precise anatomic relationships. Last but not least, radiologists using the technique can present multidetector CT data in a format familiar to clinicians: three dimensions.

"Three-D is how you improve patient care," said Dr. Elliot K. Fishman, director of diagnostic radiology and CT at Johns Hopkins Hospital. "It improves our ability to consult with

FIGURE 1. A: Selective renal arteriogram demonstrates large renal hilar aneurysm, but specific relationships of afferent and efferent branches are obscured. B and C: Volume renderings from CT angiogram clearly depict relationships of these vessels and renal parenchyma, providing a substantially more effective road map for surgical planning. (Provided by G. Rubin)

referring physicians because it puts radiologists into the 3D world in which surgeons work. Three-D CT may not change a specific diagnosis, but it will change the way patients are managed."

Some of the best examples of these newly forged collaborations have been inspired by CT angiography. Since the introduction of 16-slice CT in particular, CTA has garnered accolades for its detailed vascular portraits.

"We've done several CTA exams prior to nephron-sparing renal surgery," said Dr. Joel Platt, head of body CT at the University of Michigan, Ann Arbor. "It is almost impossible to describe the complex relationships of arteries and veins relative to the mass to the surgeon, whereas a few 3D views can accomplish this quickly and accurately."

In the brain, 3D CT accurately pinpoints aneurysm location and provides 3D mapping to clinicians planning surgery. The speed of multidetector CT is a critical advantage in trauma applications. Academic centers consider 3D CT state of the art for detecting and evaluating pulmonary embolism and aortic aneurysm endografts.

At California's Long Beach Memorial Medical Center, clinicians and radiologists confer over the best surgical plan for brain aneurysm, based on a virtual craniotomy created with 3D techniques. The surgeon describes his planned entry point. Dr. Scott Lipson, associate director of imaging at the center, then creates 3D images that show aneurysm and vessel orientation as well as surrounding anatomy based on that approach.

Three-D has also bolstered CT's already strong presence in the trauma suite. Volumetric navigation of CT data sets allows faster assessment of patients presenting to the emergency room, paving the way for rapid triage and treatment. Moreover, 3D has made it easier to communicate complex findings to surgeons, particularly in cases of penetrating trauma.

PRACTICE EVOLUTION

The increase in radiology's role in patient care, fostered by 3D CT, is an evolutionary rather than a revolutionary process, Rubin said. It's an extension of the relationship formerly shared by surgeons and angiographers.

"A lot of what we're doing with 3D CT has traditionally been done with conventional angiography," he said. "But there's no question we get more information from the 3D CT with respect to 3D relationships, which allows for greater planning and understanding."

One such case at Stanford involved a patient with an aneurysm sited close to the kidney. A standard angiogram failed to provide information that could help plan surgery. A follow-up CT with 3D volume rendering was critical to developing a specific surgical plan (Figure 1).

Stent grafting of abdominal aortic aneurysm is one procedure that directly benefits from radiologist-clinician collaboration abetted by 3D CT. Today, radiologists play an important role in stent-graft assessment, including characterization of patients before stent-graft placement and measurement of the graft postprocedure (Figure 2).

"In the late 1990s, when stent grafting of AAA was taking off, we would have weekly conferences with surgeons to go over the CT scans. We would clarify with them the measurements we were getting and help plan the procedure, using 3D images that required a 3D workstation," Rubin said. "An entire clinical enterprise has sprung up around this technology."

At Tufts-New England Medical Center in Boston, cardiologists and surgeons quickly grasped the potential 3D CT offers in vascular applications, said Dr. Neil Halin, chief of cardiovascular and interventional radiology. The interventional team is continually working with clinicians and developing new 3D protocols to suit.

"The vascular surgeons have really taken to 3D," he said. "That came about with aortic aneurysm endografts. When we first started to do these, all the planning and measuring was by hand. It was a wing and a prayer."

On a 3D workstation, those same measurements can be performed automatically once a center line through the aneurysm is identified.

"The surgeons are just blown away by this," Halin said. "Now the barrel is rolling down the hill—there are many more applications where they can see this has value."

CHANGING PERCEPTION

The changing perception of 3D presents an intriguing shift, given that many radiologists now embracing volume-rendered CT were trained when reliance on 3D was considered a crutch. The conventional wisdom of the time held that real radiologists assembled and assessed the sum of CT views in their heads. But 16-slice CT makes that particular mind trick difficult.

First-generation workstations and software were partly to blame for 3D's initial bad rap. Early software could be faulty, and workstations were slow to process images even from four-slice data sets. Some radiologists who made forays into 3D early on became frustrated and never went back. But today's hardware platforms are more robust, and volume rendering software is relatively easy to use.

"In the early years, when four-slice CT was producing hundreds of slices, the quality of 3D was limited," Fishman said. "There was a certain amount of information you could get from 3D, and a certain amount from axial imaging. Now, when you go to 1000 and 2000 slices, the information potentially available when you have formatted the data increases substantially."

Slices don't have less information than 3D, Fishman said. The difference is the amount of mining that is required to obtain the same information from slices made available by 3D.

"It's like playing 'Where's Waldo?'" he said. "You know that Waldo is there, because he is always there. But you may not be able to pull him out of the picture because of all the surrounding information. In a 3D map, you optimize the visualization, and you do it faster. It enables you to get all the information you need from the data set."

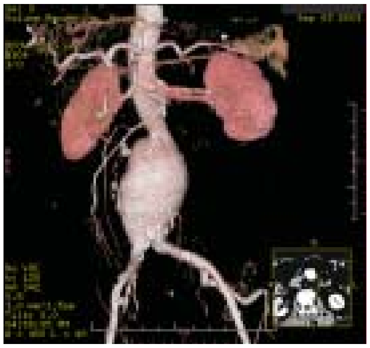


FIGURE 2. Volume-rendered 3D image of infrarenal abdominal aortic aneurysm shows the neck (aorta between renal arteries and top of aneurysm), which is critical in evaluating candidates for stent-graft therapy. It also shows orientation of iliac arteries, another important part of stent-graft evaluation. (Provided by N. Halin)

NOT JUST VASCULAR

Radiologists are contributing volumes to patient care beyond the vasculature. Cancer treatment planning with CT for specialized as well as routine applications is the focus of efforts at several medical centers. At the University of Michigan, for example, 3D CT has come to the diagnostic fore in several cases for possible resectability of pancreatic masses, according to Platt.

"Clearly, a picture (3D) is worth much more than a thousand words (long report)," he said.

Three-D CT not only contributes more to the diagnostic equation, it also promotes good customer service. That's the perspective of Dr. Brian Herts, head of abdominal imaging at the Cleveland Clinic Foundation.

Working with urology subspecialists who perform renal surgery and partial nephrectomy at the clinic, Herts developed a 3D CT program to support surgical procedures. For these oncology patients, the goal is to resect as little of the kidney as possible to preserve function and reduce the need for future dialysis. Detailed clinical information is needed to make a surgical plan.

The 3D CT gives at-a-glance information about what part of a tumor is being cut, what area of the kidney is being removed, and how those actions could compromise blood flow. Additional information is provided about what type of repairs will be needed to arteries, veins, and the collecting system (Figure 3).

In addition to 3D reconstructions that simplify the task of evaluating patients, the radiology team creates digital files that are uploaded from a workstation in the operating room and can be viewed during surgery. The same files can also be viewed from any PC connected to the clinic intranet, such as from physician offices, for surgical planning.

"Having the 3D CT simplifies the process, especially compared with when the specialists used to have to make these assessments based on axial images," Herts said. "It helps the less experienced urologists in particular. Because we're a training program, it's obvious to residents and others that this is incredibly useful."

The program was created as a collaborative effort between the urology subspecialists and Herts's team, which spent time in the operating room learning about the specialized surgery and what kinds of clinical information would be most helpful.

"This was something that the urology specialists knew they needed," he said. "The urologists had come to us and asked for it even before we actually had the capability to do it."

The team continues to refine its contributions to partial nephrectomy preoperative assessment but has also expanded 3D CT into other areas. These include evaluation of renal transplant donors and other laparoscopic procedures such as adrenalectomy. In the latter application, 3D CT is useful for mapping surgical approaches to the adrenal gland and demonstrating fat planes between the adrenal gland and the aorta, inferior vena cava, and liver. Such clinical indicators are key to the success of the minimally invasive procedure.

"It's all about efficient communication of information and being able to provide our specialists with something we could not provide before," Herts said. "We are able to communicate much more effectively by using a combination of text and pictures."

ROUTINE VIEWS

Routine abdominal imaging of cancer patients also benefits from the contributions of 3D CT. At Massachusetts General Hospital, radiologists who now routinely view coronal images for CT abdominal cases are making discoveries not seen on axial slices, said Dr. Dushyant Sahani, an assistant in radiology at MGH.

MGH radiologists began assessing the value of coronal versus axial images in the abdomen late last year. The informal project was initiated by Dr. Sanjay Saini, head of body CT, as a way to integrate 3D interpretation into routine reading and to determine applications in which doing so made a diagnostic difference.

As with CTA applications, the ability to view 3D relationships offers clear benefits in cancer patients undergoing abdominal CT. Radiologists detected metastases on coronal reformats not readily apparent on axial images in several instances. In one case, 3D imaging demonstrated that a tumor was compressing the inferior vena cava rather than invading it as suspected, clearing the way for resection (Figure 4).

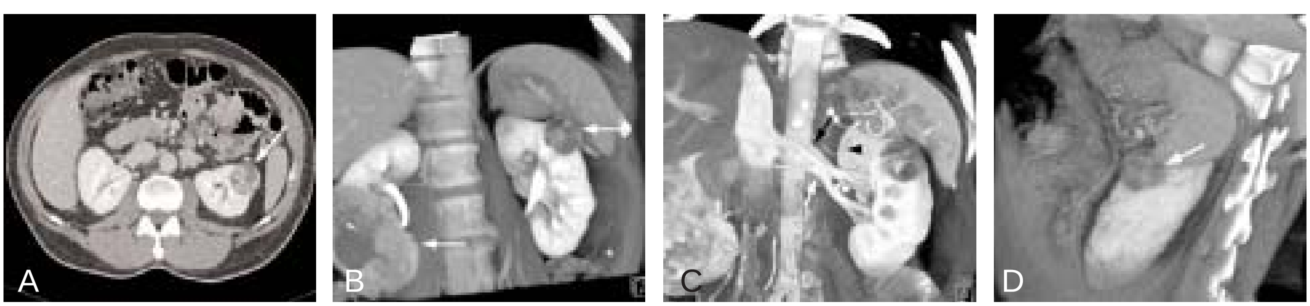
"Three-D CT makes things so much more obvious," Sahani said. "These are cases in which we are having a dramatic impact in terms of planning patient management."

While 3D vascular and other specialized types of cases may be more dramatic, the role of the technique in routine applications is important to emphasize, according to Sahani.

"When most people think of 3D, they think of the mapping capability and the ability to depict vascular anatomy. Those applications are known," he said. "But even in routine reading of studies for metastatic workup, 3D is making a big difference, not just in preoperative planning, but also in detecting metastases in patients who are simply there for cancer evaluation."

Perhaps one of the best examples of the way 3D CT is enabling radiologists to assume a larger role in patient care is in pediatric craniofacial imaging. At specialized centers such as Seattle Children's Hospital and Regional Medical Center, a multidisciplinary team of radiologists, surgeons, and other subspecialists works together to evaluate patients and plan treatment, said Dr. Raymond Sze, a staff radiologist at the center and an assistant professor of radiology at the University of Washington.

"I'm part of that team," Sze said. "Being able to create images that everyone can immediately grasp—and then be able to rotate them in a way that each person, with their particular specialty, can cut to the core of what they are most interested in—has real value. For the ENT specialist, that means being able to look at temporal bones; for the plastic surgeon, assessing sutures; eye evaluation by the ophthalmologist; and cleft palate by the maxillofacial specialist."



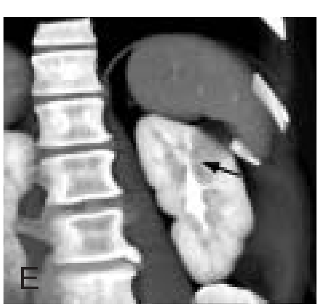


FIGURE 3. A: Axial CT of kidneys during parenchymal phase of enhancement shows small left renal tumor (arrow) extending to left of central sinus. B: Coronal oblique projection of 3D volume rendering in same patient shows bilateral renal tumors (arrows). Left renal tumor is partially exophytic; right renal tumor replaces lower half of kidney. Patient will undergo staged left partial nephrectomy and either right partial or total neprectomy. C: 3D volume rendering from vascular phase CT images. Single left renal artery (black arrow) lies just posterior and superior to left renal vein (white arrow). Small, early apical polar branch appears off left renal artery (arrowhead). D: Lateral projection of 3D volume rendering demonstrates anteroposterior relation of tumor (arrow) to normal renal parenchyma. E: Coronal 3D volume rendering from parenchymal phase images, using cut plane to see within renal parenchyma. Tumor abuts lateral calix (black arrow). This alerts surgeon that he may enter the calix and needs to repair urothelium to prevent urinary leak or fistula following surgery. (Provided by B. Herts)

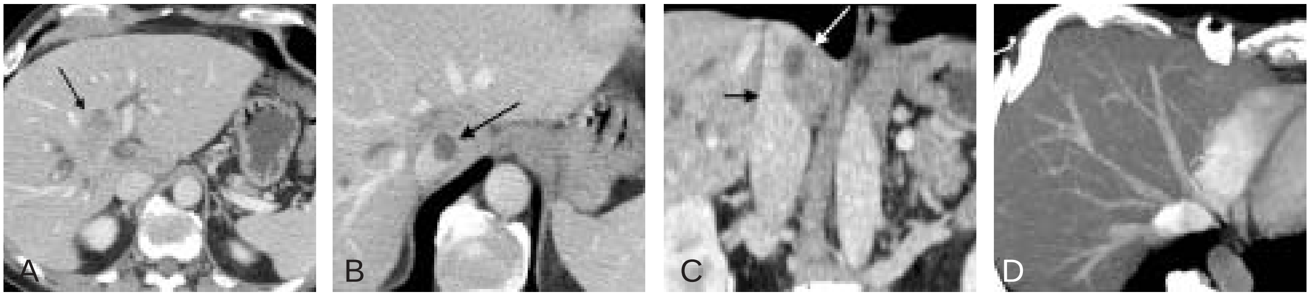


FIGURE 4. Coronal reformatted images aid cancer evaluation. 53-year-old male presented with mild epigastric pain and jaundice. A: Contrast-enhanced scan of liver, performed with 16-slice CT, revealed a 6-cm mass at liver hilum, encasing the common hepatic duct bifurcation. B: In superior aspect of liver, a filling defect was seen in intrahepatic inferior vena cava, suggesting contiguous tumor extension into the IVC. C: Reformatted coronal image demonstrates only extrinsic compression of IVC and not tumor invasion. D: Maximum intensity projection image shows hepatic venous confluence that is separate from the mass. At surgery, a cleavage plane was confirmed between mass and IVC and a curative resection was performed. Histopathology revealed cholangiocarcinoma. (Provided by D. Sahani)

NETWORK POTENTIAL

At sites with the capability to share 3D images easily across a network, collaborative opportunities between clinicians and radiologists are likely to increase. The high cost of 3D workstations relegates their use at most sites to the CT suite or specialized 3D imaging laboratories, although a few centers have invested in additional stations in the radiology reading room.

As a result, radiologist-clinician conferences about 3D data sets must take place wherever workstations are located. Typical PACS workstations are limited in their ability to handle advanced 3D data processing, a problem that several vendors, including Voxar, Vital Images, and TeraRecon, are addressing. Some products are based on software that can run on any personal computer, and others combine hardware and software. Each is based on a Windows-like interface.

TeraRecon's 3D server, AquariusNET, is hardware- and software-based. In use at Stanford, the system processes images on a high-performance server and transmits them through a network for viewing at multiple workstations or thin clients. The system integrates 3D, mass and nodule analysis, and a vascular analysis tool. Images can be viewed and manipulated at any TeraRecon workstation or PC connected to the network. The central server routes data sets to one location, solving the problem of network traffic jams when multigigabyte studies are transferred.

"We have a solid core of referring physicians who routinely access the data and manipulate it," Rubin said. "It has increased our collaborations and discussions with these folks immensely. In my mind, this is the viewbox of the future."

But not all of the barriers to widespread distribution of 3D images and the ability to manipulate them are technological. At sites with image distribution networks, some radiologists have concerns about providing clinicians with access to volumetric navigation capabilities.

Those apprehensions are partly based on the belief that cross-sectional images are obscure and require a radiologist to interpret them, unlike 3D images. Interestingly, similar concerns about image distribution and access arose when PACS was first introduced, said Dr. Eliot L. Siegel, chief of radiology and nuclear medicine at the VA Maryland Health Care System in Baltimore.

"I understand those fears," Herts said. "But radiologists have to provide the value added. If you make 3D useful enough to clinicians, they are going to want you to do it rather than trying to do it themselves. Ultimately, it increases your referrals, because you are providing extra service."

Practically speaking, it may be too late to try to hold back the tide. Clinicians are used to obtaining reports and related clinical information quickly. It is only a matter of time before access to 3D data, made possible through integration with PACS, is added to referring physicians' wish lists.

Whether that development will be met with fear or embraced remains to be seen. But as sites profiled here demonstrate, 3D CT brings the ability to contribute more critical, clinical information to patient care within reach. The challenge for radiologists is to take the next step.

"Radiologists need to come to terms with the notion that we can't keep all the toys in our closet," Rubin said. "It's a technology that benefits everybody; in particular, the person who is going to be performing surgery on a patient and needs to visualize anatomy. Facilitating access cements the role of the radiologist as central to providing services that allow clinicians to make these surgical plans and gain the most information they can from CT data."■