Multidetector Computed Tomography Angiography

Two decades of evolution in this imaging modality have produced some powerful and unprecedented options.

BY DAVID E. ALLIE, MD; CHRIS J. HEBERT, RT, RCIS; AND CRAIG M. WALKER, MD

Since its original description in 1992, computed tomography angiography (CTA) has advanced from the method of using a simple single detector to a powerful imaging multidetector system capable of acquiring 16 channels of data with rapid imaging acquisition and higher spatial resolution while simultaneously allowing patient coverage of more than 120 cm with a single scan. Computed tomography (CT) has undergone a remarkable evolution during the last 2 decades and now allows subsecond scan times, submillimeter scan thickness, and the acquisition of more than 1,000 slices per examination with a single venous injection. Optimized contrast enhancement, improved three-dimensional (3-D) volumetric data analysis, and sophisticated computer software and workstations are but several advantages of the current technology and the reason why several sources are predicting that multidetector CTA (MDCTA) will "replace 80% to 90% of all conventional diagnostic angiography."[1] CTA has already demonstrated comparability and even diagnostic superiority over conventional diagnostic angiography (CDA) in several vascular applications, including the aorta, carotid, renal, iliac, and pulmonary vessels.

> "several sources are predicting that multidetector CTA (MDCTA) will 'replace 80% to 90% of all conventional diagnostic angiography.' "

CDA with digital subtraction angiography (DSA) remains the clinical gold standard for vascular imaging, but it has multiple limitations. Magnetic resonance angiography (MRA) has been advocated to address the limitations of DSA but MRA also possesses significant limitations. In comparing MDCTA with DSA and MRA, noteworthy advantages of CTA are (1) its lower cost, its less-invasive nature (venous stick), (2) its speed, (3) its potentially requiring less contrast use and less radiation exposure, (4) its allowance of 3-D reconstruction, (5) it does not require an angiosuite or cath lab team, and (6) it has potentially fewer complications (Table 1).

MDCTA can also be used in evaluating coronary artery

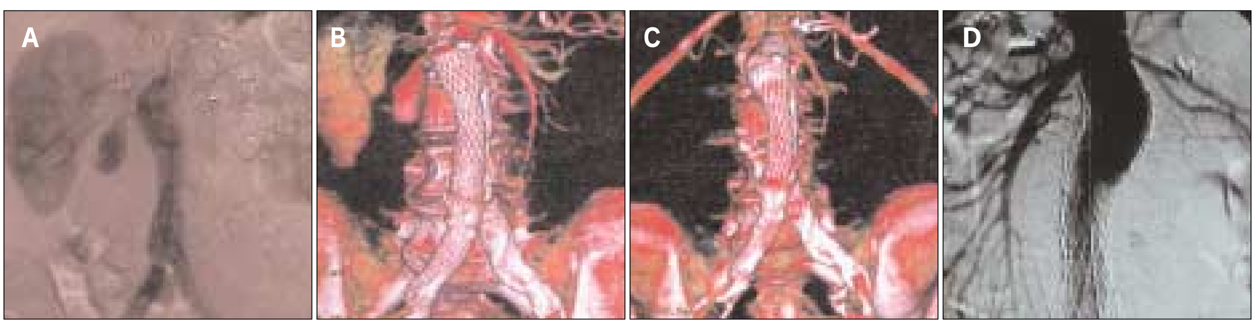

Figure 1. Symptomatic type I endoleak 6 months after EVAR in a patient with prohibitive general anesthetic risks (A). MDCTA clearly defines endoleak location, neck length and angulation, branch vessel location, and identifies stent graft migration as the endoleak etiology (B). A 28-mm aortic cuff extension seals the endoleak (C). An intraoperative angiogram demonstrates successful endoleak seal and good bilateral renal artery visualization (D). MDCTA allowed us to confidently plan treatment with an aortic cuff using a 4-inch groin incision under local anesthesia as vascular access.

TABLE 1. POTENTIAL ADVANTAGES OF MDCTA

- Retains all CT scan benefits
- Noninvasive, totally outpatient (office-based)
- Speed (scan times <60 seconds)
- Less cost and resource utilization
- Does not require angiosuite or cath lab team
- Less contrast use
- Less radiation exposure
- Nonarterial (venous) stick
- Fewer clinical risks (access complications, stroke, etc.)
- Can use in limited vascular access patients
- 3-D reconstruction
- Allows multiple views
- Improved image quality and resolution
- Allows luminal morphology evaluation
- Identification of vulnerable plaque
- Accuracy diagnosing PE
- Equivalent accuracy in most PVD areas
- Superior accuracy in several PVD areas

A. Vertebral artery	H. Calcified vessels
B. Aneurysmal disease	I. Total occlusions
C. Arch vessel disease	J. Asymmetric disease
D. Carotid artery	K. Dissections
E. Infrapopliteal vessels	L. Bypass graft surveillance
F. Stented vessels	M. SVC syndrome
G. Vascular trauma	N. Hepatic vessels

- Allows intra- and extraluminal thrombus identification
- Allows “head-to-toe” imaging with single injection
- Segmentation (editing of surrounding structures and calcium)
- Accurate in highly calcified vessels (STVR technique)
- Not affected by artifacts (clips, PPM, stents, etc.)
- Sole imaging modality for diagnosis and treatment in most PVD areas
- Nonvascular soft tissue and bone imaging
- Cardiac and CAD imaging
- Coronary calcium scoring
- Simultaneous diagnosis and staging for malignancies
- Screening for “occult neoplasms”
- Colonography
- Neuroimaging (acute stroke)
- Congenital cardiovascular anomalies (cardiac, AVM, etc.)
- Organ donor transplantations evaluations
- Noninvasive hypogastric artery evaluation for impotence

disease, chronic vascular thrombus or calcification, and nonvascular soft tissues and osseous structures. Because MDCTA does not require an arterial access, patients undergoing anticoagulation therapy or those in a hypercoagulable state need no preprocedural or periprocedural preparations. Also, MDCTA can be utilized in patients with limited vascular access (grafts, severe PVD, or absent pulses). In December 2003, our group acquired two Toshiba Aquilion (TSX-101A) 16-channel, multislice CT scan systems (Toshiba Medical Systems Corporation, Tustin, CA) with a Vitrea 2 3-D workstation (Vital Images, Plymouth, MN), primarily to provide noninvasive imaging for our large PVD patient population. This article describes our early outpatient office experience with MDCTA and how it has changed and influenced our patient care.

IMAGING TECHNIQUE

Three major principles of MDCTA are (1) to achieve an adequate level of arterial contrast enhancement during acquisition, (2) to provide cephalocaudad coverage of the targeted anatomy during an early sustainable breath hold interval (<20 seconds), and (3) to time the onset of CT acquisition after contrast injection accurately so that the first circulation enhancement is obtained from the beginning of acquisition to the end of acquisition. An important aspect of efficient clinical MDCTA is an accurate request of information desired about each patient’s suspected vascular pathology. This requires developing close communication between the physician and MDCTA team, especially during the team’s early experience with this technology.

Typically, 80 mL to 100 mL of an intravenous nonionic contrast agent are administered through a 20-gauge plastic venous cannula in an antecubital vein at an injection rate of 4 mL/s to 6 mL/s. In clinical MDCTA, the contrast enhancement, acquisition parameters, coverage speed, and circulating time are accurately determined by protocols based on the clinical information requested, imaging modality used, and patient-specific variables (age, body size, cardiac output, renal function, etc.). With current MDCTA technology, it is reasonable to obtain images from the clavicles or abdomen down to the knees or the abdomen

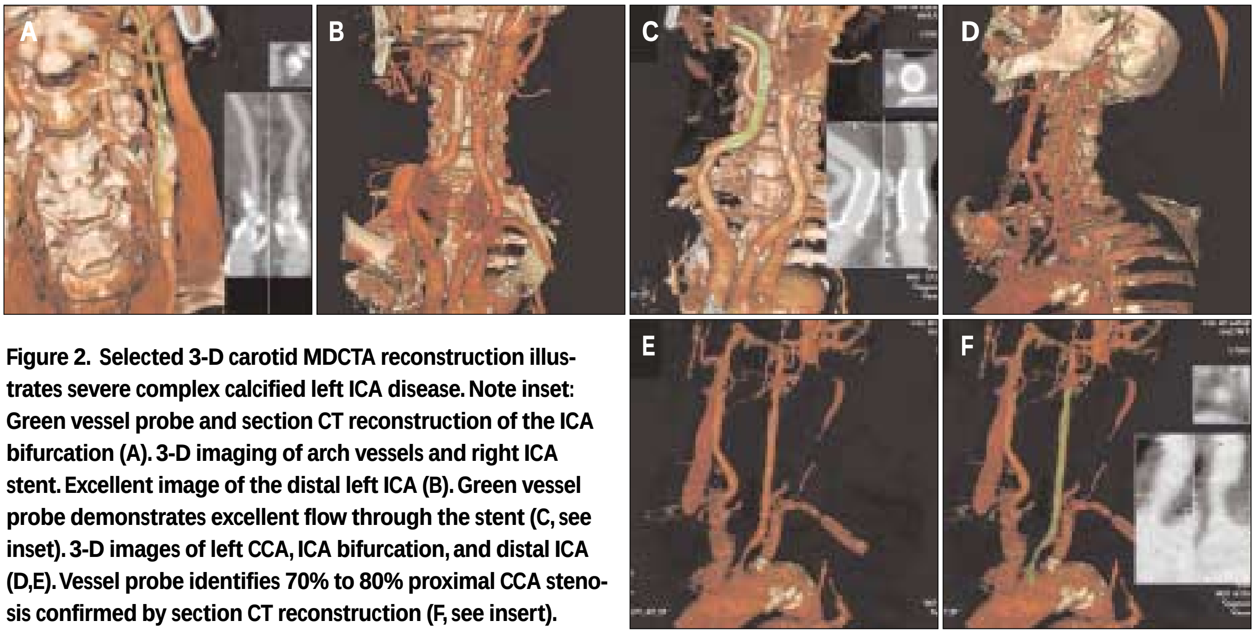

Figure 2. Selected 3-D carotid MDCTA reconstruction illustrates severe complex calcified left ICA disease. Note inset: Green vessel probe and section CT reconstruction of the ICA bifurcation (A). 3-D imaging of arch vessels and right ICA stent. Excellent image of the distal left ICA (B). Green vessel probe demonstrates excellent flow through the stent (C, see inset). 3-D images of left CCA, ICA bifurcation, and distal ICA (D,E). Vessel probe identifies 70% to 80% proximal CCA stenosis confirmed by section CT reconstruction (F, see insert).

and pelvis to the patient's feet, all within 30 seconds. After observing my first MDCTA, I commented, "This is like shooting 16 angiograms all from different angles, simultaneously, in color, and in just a few seconds."

CLINICAL APPLICATIONS

Abdominal Aortic Aneurysms (AAAs)

Conventional CT scanning and CDA have been considered the gold standard for AAA diagnosis, treatment-planning recommendations, and postoperative surveillance, especially since the introduction of aortic stent grafts and endovascular aneurysm reconstruction (EVAR). Besides being noninvasive, MDCTA offers several advantages over traditional imaging, including (1) superiority in identifying mural thrombus and evaluating periaortic tissues for rupture, endoleak, and inflammatory AAA identification; (2) more precise determinations of size, length, angulation, and transverse dimensions of the AAA superior neck; (3) more accurate characterization of postprocedural AAA endograft deformation, kinking, or migration with identification of branch vessels; (4) 3-D reconstruction allows improved assessment of iliac tortuosity and detection of endoleaks; and (5) post-EVAR AAA volume determinations may allow earlier detection of device failure, rupture, or endoleak.[2]

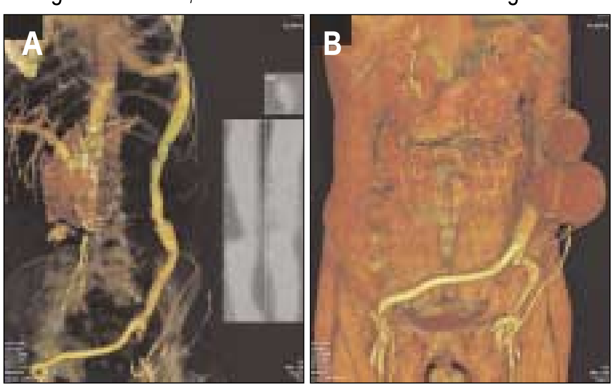

Figure 3. Selected 3-D thoracoabdominal graft reconstruction in a dialysis patient with occlusion of both renal arteries and abdominal aorta who presented with left leg pain and a left flank mass. Note: Occlusion of the left leg graft limb and irregular 80% stenosis of the thoracic graft (A). 3-D soft tissue reconstruction identifies multiple seromas compressing the graft (B).

Traditional imaging can overestimate the true AAA neck diameter and length because of obliquity, thereby influencing treatment recommendations and outcomes. MDCTA has replaced traditional CT scanning and DSA in almost all aspects of our AAA pretherapy recommendations and posttreatment follow-up (Figure 1).

Carotid Artery Disease

The degree of stenosis of the internal carotid artery (ICA) has been scrutinized more than any other peripheral vessel because the degree of stenosis is associated with the risk of stroke. Landmark trials during the last 2 decades have demonstrated reduced stroke rates in both symptomatic and asymptomatic patients, with ICA stenosis of ≥50% to 60% treated by carotid endarterectomy (CEA).[3,4] Several equally landmark interventional carotid artery stent (CAS) trials have shown at least equivalency and even improved early outcomes with ICA stenting versus surgery, challenging the gold standard for ICA disease treatment.[5,6] This will also challenge our gold standard for ICA imaging because optimal CAS will require more detailed and comprehensive information on the aortic arch and entire extra- and intracranial carotid artery system than is currently required for surgery.

CDA with DSA remains the gold standard for ICA imaging but has a definite risk of periprocedural stroke. DSA is performed in limited projections, whereas MDCTA provides multiple views. DSA has recently been shown to underestimate the degree of ICA stenosis when cross-sectional lumens of surgical specimens were compared with DSA.[7] With use of helical MDCTA, Elgersma et al[8] identified additional (16%) ICA suitable for CEA compared with DSA, thereby further underscoring the complexity of the ICA bifurcation and the need for multiple views to accurately determine the degree of stenosis.

Carotid duplex ultrasound (DU) has been known to have a >90% sensitivity and specificity in diagnosing ICA disease but is still operator-dependent, moderately time-consuming, and gives limited information on the distal extracranial ICA and intrathoracic common carotid artery and no information on the intracranial or arch vessels. Several reports have shown the diagnostic accuracy of carotid CTA for 70% to 99% ICA stenosis to have a sensitivity of 100% and a specificity of 94% to 100%.[9,10] Multiplanar reconstruction methods will allow cross-sectional luminal and plaque morphology evaluation and potentially provide additional pertinent clinical information.[11]

A routine carotid MDCTA examination includes 30 cm of cephalocaudad coverage from the ostium of the aortic arch vessels to the circle of Willis at the base of the skull, allowing accurate decision-making recommendation regarding a patient's candidacy for CAS with a single noninvasive examination. Currently, we are not routinely imaging intracranial vessels, but this capability is possible. CTA neuroimaging has been found to compare favorably with DSA in evaluating acute stroke, arterial dissections, and intracranial aneurysms, with reduced patient risks.[12] Excellent proximal vertebral artery imaging is available on a routine carotid MDCTA, allowing identification of additional patients who may benefit from endovascular intervention.

> "Traditional imaging can overestimate the true AAA neck diameter and length because of obliquity, thereby influencing treatment recommendations and outcomes."

Aortic arch vessel anatomy, tortuosity, and ostial arch vessel disease (AVD), along with distal ICA tortuosity are frequently significant limitations to carotid stenting because placement of a distal protection device has been required in most CAS trials. Isolated ostial AVD is thought to be rare, with a reported incidence of 1.8% and is reported even less frequently (0.6%) in patients undergoing CEA.[13,14] This most likely underestimates the true incidence of AVD because many selective carotid angiograms are obtained without arch angiography and CEA is often recommended on DU alone. Our group reported a 4.3% (34 of 784) incidence of simultaneous significant ostial AVD in patients requiring CEA, which further raises questions regarding the underestimation of AVD.[15] MDCTA now allows accurate assessment of ICA stenosis, access vessel and distal ICA tortuosity, and the detection of ostial AVD, potentially allowing a determination of CAS versus CEA candidacy noninvasively without the inherent risks of DSA. In our experience, carotid MDCTA has almost replaced CDA and DSA as a diagnostic tool and increasingly important carotid treatment and surveillance decisions are made relying on MDCTA information alone (Figure 2).

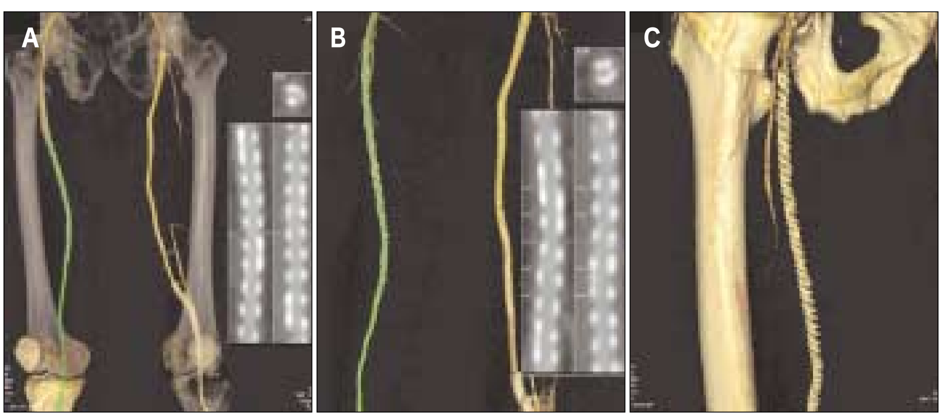

Figure 4. 3-D MDCTA reconstruction of patient with a long segment right SFA stent and a left femoral-popliteal vein bypass graft after PTA/stenting of the distal anastomosis (self-expanding nitinol). Note the excellent flows through the right SFA stent (A, see inset). Osseous segmentation capability further defines the SFA stents and bypass graft (B). 3-D reconstruction with magnification further defines the double-helical design of the multiple patent aSpire stents (Vascular Architects, Inc., Santa Rosa, CA) (C).

Renal and Mesenteric Arteries

The benefits of renal artery stenosis (RAS) diagnosis and revascularization have been proven in patients with severe hypertension, refractory conges-

Figure 5. 3-D MDCTA reconstruction of a patient after right popliteal PTA/stenting (self-expanding nitinol) and left tibioperoneal trunk (TPT) PTA/stenting with an Intracoil (eV3, Plymouth, MN). Note the critical right TPT and anterior tibial disease and the aberrant left posterior tibial artery with diffuse disease (A). Image depicting diffuse significant midinfrapopliteal disease with good pedal targets (B). MIP of left leg identifying noncalcified PTA target just above the ankle (C). Vessel probe confirms nonobstructive 2.4-mm "soft" tibial target (D).

tive heart failure, angina, and patients with declining renal function, underscoring the importance of a safe, accurate, simple noninvasive diagnostic tool. The limitations of abdominal vessel DU are well known. 3-D abdominal MDCTA has addressed many of these limitations, and Berengi et al[16] recently reported 100% accuracy and sensitivity comparing CTA with DSA in RAS. Galanski et al[17] reported the sensitivity and specificity of MDCTA versus DSA in RAS as 92% and 95%, respectively. Recent reports by Abu Rahma et al[18] and our group[19] have identified benefits with PTA/stenting in appropriately diagnosed patients with mesenteric artery disease (MAD). There are no such reports of MDCTA evaluating MAD, but our initial experience indicates MDCTA will be as accurate in diagnosing MAD as it is in RAS. Stents are very well imaged, allowing the potential for improved accuracy in detecting restenosis, which has a 10% to 20% incidence after renal and mesenteric PTA/stenting.

Abdominal MDCTA is rapidly replacing DU as our primary diagnostic and surveillance tool in evaluating RAS and MAD. In patients with RAS, the 16-channel MDCTA scanner can pinpoint the juxtarenal aorta and shorten acquisition times to <10 seconds and reduce contrast load to <40 mL.

Aortoiliac Occlusive Disease (AIOD)

An "endovascular first" approach toward AIOD revascularization was adopted in our practice well over a decade ago, and acceptable long-term results in iliac PTA/stenting have substantiated this policy. DSA fails to detect aneurysmal disease, and the diagnostic accuracy is adversely affected by vascular calcification. Single-planar DSA frequently misses eccentric lesions, which are prevalent posteriorly at the distal aortic bifurcation and entire iliac artery segment. DSA oftentimes poorly visualizes vessels distal to a more proximal stenosis or occlusion.

Native common femoral artery (CFA) disease is not uncommon and frequently patients will present with stick-site injuries from multiple previous percutaneous procedures. Avoiding the diagnostic arterial stick with DSA has significant clinical implications. We have found MDCTA to be particularly useful in avoiding "sticking into disease" and planning our endovascular treatments.

Several recent studies have shown the sensitivity and specificity of MDCTA in detecting significant AIOD to be >96%,[20] and Rubin et al[21] recently reported 100% concordance between MDCTA and DSA in AIOD using 2.5-mm slices covering 120 mm in 60 seconds of acquisition time. MDCTA has been shown to be superior to DSA in evaluating vascular trauma, dissections, and popliteal aneurysms. In our practice, several asymptomatic >5-cm AAA and significant iliac and popliteal aneurysms are diagnosed each month in patients imaged for suspected AIOD. Recent reports have shown a reduction in contrast use and a fourfold reduction in radiation exposure comparing MDCTA and DSA in diagnosing AIOD.[22]

Our routine MDCTA for AIOD includes cephalocaudad coverage from the supraceliac aorta to the proximal thigh (approximately 30-40 cm). Scanning parameters can be adjusted to achieve a reduced contrast load (<75 mL) with scan times ≤30 seconds. It is always recommended to scan both CFAs because most endovascular procedures are performed via a CFA approach. MDCTA is now our diagnostic mode of choice for diagnosing and following AIOD, and >90% of our surgical and endovascular treatment recommendations are influenced by MDCTA (Figure 3).

Infrainguinal Disease

The SFA and crural vessels are among the most calcified vessels in the body and are therefore a challenge to accurate assessment of the degree of stenosis. The high incidence of vessel occlusions, asymmetric disease, and vascular calcifications are highly characteristic of infrainguinal disease and known limitations of DSA and DU. Known advantages of MDCTA include improved accuracy in vascular occlusions, calcifications, and patients with asymmetric disease. The speed and quality of image acquisition with MDCTA easily compensates for severe ipsilateral lower-extremity disease (unilateral 100% SFA occlusions).

There are no published data comparing DSA or DU with MDCTA in infrainguinal vessel disease, but several promising image enhancement-processing techniques are available, especially in infrapopliteal vessels. Curved planar reformation and semitransparent volume rendering with automated measurements are new 3-D imaging modalities that improve the accuracy of MDCTA in highly calcified vessels.[23] The editing of boney structures (osseous segmentation) is now available at the workstation using automatic region growing imaging techniques. Segmentation of the tibia, fibula, and tarsal osseous structures can have significant clinical implications in achieving limb salvage. Maximum intensity projection is a 3-D image reconstruction that allows maximal contrast opacification and vessel interrogation (Figure 4).

Rubin et al[21] reported identification of 26 additional infrainguinal arterial segments that were not identified with DSA using MDCTA due to the improved arterial opacification distal to an occluded segment. Identification of distal targets could identify patients for tibial bypass or endovascular revascularization who otherwise may only be offered amputation. This becomes especially important with the excellent >90% 6- to 12-month limb salvage rates reported by Laird et al[24] utilizing the excimer laser (Spectranetics, Colorado Springs, CO) in the multicenter LACI trial. Similar results were reproduced by our group[25] in a "LACI-equivalent" report. MRA is considered the gold standard in imaging pedal vessels, but MRA is not reliable in calcified vessels, it is time-consuming, it is not widely available, and it is affected by retrograde flow artifacts, existing stents, and pacemakers. We have found infrainguinal MDCTA invaluable in the diagnosis, treatment, planning, and follow-up of our infrainguinal interventions, especially in infrapopliteal vessels in which DU is rarely helpful.

Today, our most frequently utilized imaging is an abdominal MDCTA with bilateral runoff to the feet. This can usually be accomplished with 80 mL to 100 mL of contrast injected over approximately 120 cm with a scanning duration of less than 30 seconds. In the future, new 32-channel and 64-channel MDCTA scanners have the possibility of scanning the entire vascular system of a 170-cm-tall patient (from head to toe) in less than 15 seconds.

Bypass Graft Surveillance

Both infrainguinal bypass grafts and endovascular treated vascular segments have been shown to require a 20% to 30% secondary intervention rate to achieve an acceptable 1- to 2-year patency, which underscores the need for noninvasive postprocedural surveillance.[26] DU has been the gold standard in the postsurgical patient but limitations of DU that are not found with MDCTA include difficulty in following nonanatomically placed grafts, inaccuracy in cases with inflow lesions, multiple graft lesions, A-V fistulas, inability to pinpoint stenosis, and failure to display tibial or pedal vessels distal to the anastomosis. Willmann et al[27] reported a 98% sensitivity and specificity in comparing DSA versus four-channel MDCTA in 85 bypass grafts. In our experience, MDCTA has allowed accurate diagnosis and planning for graft reintervention, whereas DU has not (Figure 5).

Cardiac Applications

Cardiac MDCTA differs from routine MDCTA for PVD primarily due to the dynamic motion of the heart and static nature of PVD. Detector, table, and imaging parameters vary greatly from those used in PVD. The scan times are much longer and oral and intravenous beta-blockers are required to keep the heart rate at <60 bpm. Current MDCTA is unable to accurately grade coronary artery stenosis, especially in small vessels. However, cardiac MDCTA has shown a high negative predictive value for significant disease and the sensitivity, specificity, and reproducibility of MDCTA for the detection of coronary calcification has been found to be higher than electron beam CT.[28]

MDCTA has been found to identify intracoronary thrombus, therefore it may have a promising role in diagnosing acute coronary syndromes. Other potential future applications include post-PCI–stenting evaluation and vulnerable plaque identification. We are currently not performing cardiac MDCTA for CAD screening in patients with stable angina, but we are increasingly using MDCTA to evaluate coronary artery bypass grafts and pulmonary venous anatomy in planning electrophysiological procedures.

Additional Vascular Applications

MDCTA is rapidly replacing traditional imaging modalities in patients with acute and chronic aortic syndromes (dissections and aneurysms), acute and chronic PE, congenital cardiovascular anomalies, cardiothoracic and vascular neoplasms and trauma, acute stroke, hepatic vascular evaluations, organ donor transplantations, complex vascular anomalies and malformations, and superior vena cava syndrome.[11,19,20,28] MDCTA has shown a sensitivity and specificity of 78% to 100% in diagnosing PE because contrast enhancement techniques using sub–1.25-mm slice thickness allows visualization of small PE, even in fifth- and sixth-generation pulmonary vessels.[29] With >650,000 newly diagnosed cases of PE each year in the US, MDCTA has now given us a quick, safe, and accurate noninvasive tool to diagnose PE, in which early treatment can reduce mortality rates from 30% to approximately 2% to 10%.[29]

Additional Nonvascular Applications

Contrast-enhanced thoracic CT is becoming increasingly important in evaluating pulmonary nodules, differentiating between benign and malignant disease, staging, treatment, and in thoracic surgical follow-up. Swensen et al[30] reported a 98% sensitivity and 58% specificity for malignancy using contrast-enhanced CT in evaluating 356 lung nodules ranging from 5 mm to 40 mm in diameter. Widespread single- and dual-detector CT screening for lung cancer has not been thought to be cost-effective and has a high false positive rate. It is hopeful that in the future, MDCTA screening in high-risk patient populations will be clinically beneficial and cost-effective.

The lifetime risk of colorectal cancer in the US is 5.7% and screening for fecal occult blood has shown a 33% reduction in mortality.[31,32] CT colonography is gaining popularity as a noninvasive screen for cancer and has a sensitivity of 90% to 94% and a specificity of 72%.[28] Currently, CT colonography requires special patient preparation, colon inflation, and is time-consuming. Total body CT scanning for "occult" neoplasms has been promoted but currently lacks randomized cost and clinical analysis. We have not adopted cancer screening but do realize the potential clinical benefits to our large populations of elderly at risk patients, and the potential to build referral relationships with primary care physicians, oncologists, and radiologists.

We currently have a radiologist interpret all nonvascular CT imaging and review all vascular MDCTA studies. Our cardiologist and surgeons currently also interpret each CTA. Increasingly, we are utilizing traditional CT imaging for more noncardiovascular applications (ie, CT of the head, chest, and lumbar spine, and so forth). Having this imaging modality rapidly available in our outpatient office setting has greatly simplified and facilitated the overall clinical work-up and follow-up of our patient population who oftentimes has multiple medical problems.

LIMITATIONS

Contrast-induced nephropathy (CIN) has been the single biggest concern and adjustment to our outpatient practice. Most patients with a creatinine (CR) ≤1.8 mg/dL can tolerate an intravenous dose of 100 mL of nonionic low osmolar contrast without clinical sequelae. Multiple protocols are available for MDCTA in patients with chronic renal insufficiency. The physicians, nurses, and MDCTA team must evaluate the renal function of each patient considered for CTA. In low-risk CIN patients (CR <1.4 mg/dL) no preparation is necessary.

In higher-risk CIN patients (diabetic, CR 1.4 to 2 mg/dL), a renal preparation protocol is instituted that includes Mucomyst (Bristol-Myers Squibb, New York, NY) 600 mg p.o. b.i.d. for four doses beginning the day before MDCTA. Intravenous fluids of D5 1/2 NS at 100 mL/hr for 6 hours prior to CTA is administered in our holding area for patients with the greatest CIN risk (CR 1.7 to 2 mg/dL). For patients with CR >2 mg/dL, hospitalization for nephrology consultation and further renal preparation is recommended. A 1-week follow-up CR is obtained from all outpatient CTA patients.

SUMMARY

The 16-channel multidetector CTA imaging system has revolutionized our PVD practice in only a few short months. MDCTA has become our noninvasive imaging modality of choice and is rapidly replacing CDA and DSA as our gold standard for diagnostic PVD evaluation. MDCTA allows us to confidently make clinical planning and treatment decisions on our endovascular and surgical patients much more efficiently, accurately, and at less risk and costs to the patient than before with conventional imaging techniques. Each week, we are discovering new clinical uses for this new technology, which will translate to improved overall outcomes for our patients. ■

David E. Allie, MD, is Director of Cardiothoracic and Endovascular Surgery at the Cardiovascular Institute of the South in Lafayette, Louisiana. He has disclosed that he has no financial interest in any product or manufacturer mentioned herein. Dr. Allie may be reached at (800) 582-2435; David.Allie@cardio.com.

Chris J. Hebert, RT, RCIS, is Director of Technology at the Cardiovascular Institute of the South in Lafayette, Louisiana. He has disclosed that he has no financial interest in any product or manufacturer mentioned herein. Mr. Hebert may be reached at (800) 582-2435; Chris.Hebert@cardio.com.

Craig M. Walker, MD, is Medical Director and Founder, Cardiovascular Institute of the South, in Houma, Louisiana. He has disclosed that he has no financial interest in any product or manufacturer mentioned herein. Dr. Walker may be reached at (800) 445-9676; Craig.Walker@cardio.com.

1. Fishman EK. The use of contrast in CT angiography applications. *Appl Radiol*. 2003;(suppl):64-49.
2. Lee JT, Lee J, Aziz IN, et al. Volume regression of abdominal aortic aneurysm and its relation to successful endoluminal exclusion (abstract). Paper presented at: 56th Annual Scientific Meeting of the Society of Vascular Surgery; June 2002; Boston, MA.
3. North American Symptomatic Carotid Endarterectomy Trial Collaborators. Benefits of carotid

endarterectomy in patients with moderate or severe stenosis. *N Engl J Med*. 1998;339:1415-1425.
4. Executive Committee for the Asymptomatic Carotid Atherosclerosis Study. Endarterectomy for asymptomatic carotid artery stenosis. *JAMA*. 1995;273:1421-1428.
5. Yadav J. Stenting and angioplasty with protection in patients at high risk for endarterectomy (The SAPPHIRE Study). AHA Scientific Sessions; November 2002; Chicago, IL.
6. Wholey M. The ARCHeR trial: prospective clinical trial for carotid stenting in high surgical risk patients-preliminary 30-day results. Presented at: American College of Cardiology Annual Meeting. March 2003;13:47-55.
7. Pan XM, Saloner D, Reilly LM, et al. Assessment of carotid artery stenosis by ultrasonography, conventional angiography, and magnetic resonance angiography: correlation with ex vivo measurement of plaque stenosis. *J Vasc Surg*. 1995;21:82-89.
8. Elgersma OEH, Buijs PC, Wust AFJ, et al. Maximum internal carotid arterial stenosis: assessment with rotational angiography versus conventional intra-arterial digital abstraction. *Radiology*. 1999;213:777-783.
9. Leclerc X, Godefroy O, Lucas C, et al. Internal carotid artery stenosis: CT angiography with volume rendering. *Radiology*. 1999;210:673-682.
10. Link J, Brossmann J, Penselin V, et al. Carotid artery bifurcation: preliminary results of CT angiography and color-coded duplex sonography compared with digital subtraction angiography. *Am J Roentgenol*. 1997;168:361-365.
11. Hirai T, Korogi Y, Ono K, et al. Maximum stenosis of extracranial internal carotid artery: effect of luminal morphology on stenosis measurement by using CT angiography and conventional DSA. *Radiology*. 2001;221:802-809.
12. Zinreich SJ, Takhtani D. CT angiography in neuroimaging. *Appl Radiol*. 2003;(suppl)34-41.
13. Dietrich EB, Marx P, Wrasper R, et al. Percutaneous techniques for endoluminal carotid interventions. *J Endovasc Surg*. 1996;3:182-202.
14. Akers DL, Markowitz IA, Kerstein MD. The value of aortic arch study in the evaluation of cerebrovascular insufficiency. *Am J Surg*. 1987;154:230-232.
15. Eisenhauer MD, Wicks AB, Olson JP, et al. Prevalence of aortocoronary graft marker use and the factors affecting this decision. *J Card Surg*. 1998;13:194-199.
16. Galanski M, Porkop M, Chavan A, et al. Accuracy of CT angiography in the diagnosis of renal artery stenosis [in German]. *Rofo Forschr Geb Rontgenstr Neuen Bildgeb Verfahr*. 1994;161:519-525.
17. Beregi JP, Elkohen M, Wattinne L. Helical CT angiography compared with arteriography in the detection of renal artery stenosis. *Am J Roentgenol*. 1996;167:495-501.
18. Abu Rahma Ali, Stone PA, Bates M, et al. Angioplasty/stenting of the superior mesenteric artery and celiac trunk: early and late outcomes. *J Endovasc Surg*. 2003;10:1046-1060.
19. Allie DE, Hebert CJ, Khan MA, et al. Chronic mesenteric ischemia: role of angioplasty/stenting in celiac and SMA disease. J Endovasc Surg. 2004;11(suppl):I-47.
20. Martin ML, Tay KH, Machan L, et al. Multidetector CT angiography of the aortoiliac system and lower extremities: a prospective comparison with digital subtraction angiography. *Am J Roentgenol*. 2003;180:1085-1091.
21. Rubin GD, Schmidt AJ, Sofilos MC, et al. Multi-detector row CT angiography of lower extremity arterial inflow and runoff: initial experience. *Radiology*. 2001;221:146-158.
22. Katz DS, Hon M. CT angiography pf the lower extremities and aortoiliac system with a multidetector row helical CT scanner: promise of new opportunities fulfilled. *Radiology*. 2001;221:7-10.
23. Portugaller HR, Schoellnast H, Hausegger KA. Semitransparent volume-rendering CT angiography for lesion display in aortoiliac arteriosclerotic disease. *J Vasc Intervent Radiol*. 2003;14:1023-1030.
24. Laird JR. Final LACI report. Presented at: TCT; September 2003, Washington, DC.
25. Allie DE. Excimer laser assisted angioplasty in severe infrapopliteal disease: a "LACI-equivalent" update. Abstract presentation: ISET; January 2004, Miami, FL.
26. Dalman RL, Taylor LM Jr. Basic data related to infrainguinal revascularization procedures. *Ann Vasc Surg*. 1990;4:309-312.
27. Willmann JK, Mayer D, Weishaupt D, et al. Evaluation of peripheral arterial bypass grafts with multi-detector row CT angiography: comparison with duplex US and digital subtraction angiography. *Radiology*. 2003;229:465-474.
28. Hunink MG, Gazelle GS. CT screening; a trade-off of risks, benefits, and costs. *J Clin Investig.* 2003;11:1612-1619.
29. Kavanagh EC, Murray JG. Risk of pulmonary embolism after negative MDCT pulmonary angiographic findings. *Am J Roentgenol*. 2004;182:499-504.
30. Swensen SJ, Viggiano RW, Midthun DE, et al. Lung nodule enhancement at CT: multicenter study. *Radiology*. 2000;214:73-80.
31. McMahon PM, Gazelle GS. Colorectal cancer screening issues: a role for CT colonography? *Abdom Imag.* 2002;27:235-243.
32. Pignone M, Rich M, Teutsch SM, et al. Screening for colorectal cancer in adults at average risk: a summary of the evidence for the US Preventive Services Task Force. *Ann Intern Med*. 2002;137:132-141.

ENDOVASCULAR TODAY SUBMISSION GUIDELINES

If you would like to submit an article for publication in *Endovascular Today*, first query in writing with an outline of your proposed article.

Editorial Policies. All articles published in *Endovascular Today* are reviewed by our Chief Medical Editor and Editor-in-Chief, who have sole discretion to accept, reject, or edit any article submitted for consideration. All articles must be original and must not have been published elsewhere.

Format. We accept manuscripts in Microsoft Word format. Drafts should be e-mailed to the Editor-in-Chief.

Deadlines. All assigned work must be submitted by the first day of the month, 2 months prior to publication.

Length. Unless otherwise agreed to by our Editor-in-Chief, articles shall be at least 1,200 words in length.

Author Information. Please include (1) a complete article title, (2) the author (s) full name(s), academic degree(s), affiliation(s), financial connection to any products mentioned, and (3) full address for correspondence, including complete mailing address, fax number, telephone number, and e-mail address.

Artwork. A minimum of two figures (and related legends) should be supplied with each article. Digital files can be sent in JPG, TIF, or EPS format, and should be approximately 300 dpi at 4 inches wide. If sending via e-mail, JPEG images are preferred. Original slides and photos are also acceptable. Please be sure to indicate numbering and orientation of images.

References. References should be numbered in the order in which they appear in the text and listed at the end of the manuscript. Unpublished data (such as papers submitted but not yet accepted for publication and personal communications) should be cited parenthetically within the text.

Direct queries to Pete Christy, Editor-in-Chief, at pchristy@bmc-today.com or (484) 581-1800, ext. 25. Address correspondence to Endovascular Today, *c/o Bryn Mawr Communications II LLC, 1008 Upper Gulph Road, Suite 200, Wayne, PA 19087.*