CT angiography is an emerging technique for noninvasive evaluation of peripheral vascular disease. CT was first used to evaluate the peripheral vasculature in the early 1990s. Single-detector spiral CT scanners were limited by their inability to cover the whole vasculature from the diaphragm to the feet quickly enough to track a contrast bolus. These limitations were overcome with the advent of multislice CT scanners in 1998. MSCT images are comparable to those obtained with catheter angiography (Figure 1).

MSCT provides excellent visualization of peripheral vessels because of its improvements in scanning speed, distance, and slice thickness, which result in marked improvement in z-axis resolution. Nearly isotropic resolution can be obtained in patients with examinations that are fast enough to be performed in a single breath-hold. Compared with catheter angiography, MSCT angiography has several advantages. Its speed of acquisition makes the procedure quicker than conventional catheter angiography, no arterial access is required, patients can leave the department almost immediately after the examination, and no postprocedure evaluation is necessary. Additionally, the radiation dose to the operator and the patient is lower, although further research on patient dose is needed to gather conclusive information.

The risk of exposure to blood products is vastly reduced compared with digital subtraction angiography (DSA). Evaluation of coagulation status, a common problem in a significant proportion of these patients, is unnecessary, which may make MSCT angiography the investigation of choice for anticoagulated patients. Finally, CT usually requires less intensive staffing levels than angiography, and accessibility to CT tends to be better. The technique provides both vascular and nonvascular cross-sectional tissue and organ information. Three-D models can be viewed from any angle to best see a stenosis, specific vessel, or graft anastomosis.

With the introduction of 16-slice CT units-and in the future, 32- and 64-slice scanners-further improvement has occurred in spatial resolution in the z-axis, with thinner slices. The patient can be scanned from the diaphragm to the toes in less than 32 seconds. The increase in scan speed enables contrast rates of up to 5 mL per second and excellent opacification of vessels. The resulting images are of good diagnostic quality right down to the foot vessels (Figures 2 and 3).

We scan our patients using a 16-slice Lightspeed 16 Pro CT scanner from GE. A dose of 150 mL of Omnipaque (350 mg/mL) (Amersham Health) is used for each examination. The intravenous contrast is administered using a Medrad Envision CT pressure injector, which enables a contrast rate up to 5 mL/sec. Images are routinely obtained at 1.25 mm and reconstructed with 0.6-mm overlap. The images are then postprocessed in axial, sagittal, and coronal planes and converted into 3D projections using various reconstruction techniques. They can be displayed as a complete single angiographic image from the diaphragm to the toes, or a data set of three different areas can be reconstructed separately and displayed individually as aortoiliac, femoropopliteal, and calf segments.

Images can be further manipulated and subtracted to either show bone or remove it (Figure 4). Vessels in the region of the ankle and foot are easier to visualize without removing bone, due to the anatomic configuration of the area. Newer software techniques allow subtraction of calcification in the walls of arteries to reveal stenoses and occlusions in calcified vessel segments. Various 3D reformatting techniques are currently used in practice. The most common are...
multiplanar reformation (MPR), curved planer reformation (CPR), maximum intensity projection (MIP), surface-shaded display (SSD), and volume rendering (VR). In our hospital, we commonly use MIP and VR reformation techniques, both of which have advantages and disadvantages (Figure 5 and table). Oral contrast should not be administered before an examination because these techniques rely on contrast differences between enhanced vascular lumen and surrounding structures.

**DISEASE EVALUATION**

MSCT angiography can accurately evaluate the arteries down to the foot (Figures 5 and 6). It can depict varying degrees of stenoses/occlusions (Figures 7, 8, and 9), and it can accurately depict lesions that require treatment. Various studies have found its overall accuracy to be better than 90%, compared with DSA as the gold standard.

Source images should be correlated with the angiographic image, as this helps confirm the abnormality and also provides information about extrinsic pathology around the lesion. MSCT angiography is also accurate in assessing peripheral arterial bypass grafts. It is useful for detection of graft-related complications such as stenoses, occlusion, aneurysms, and fistulous communications (Figures 10 and 11). It compares favorably with duplex ultrasound in this application.

The technique provides an angiographic road map for planning further therapeutic intervention, which most patients require. General radiologists who have a good grasp of modern workstation manipulation can learn to interpret the images easily, leading to better utilization of resources for more complex interventions.

In our series of patients, the overall accuracy of the technique has exceeded 90%, which concurs with various published series. We started performing CTA more than three years ago and have used it regularly since acquiring our 16-slice MSCT scanner about two years ago. Our routine CTA list includes many applications, including visceral and peripheral angiography in all areas where the technique has a well-documented role. We have scanned more than 300 patients with a clinical presentation suggesting peripheral vascular disease.

After screening with Doppler ultrasound, we use CTA as the initial angiographic modality in most patients, which enables us to reserve more of our time for interventional procedures. We routinely use CTA to image the arteries of the lower limbs, and our imaging protocols have evolved to integrate CTA into our diagnostic pathways.

After clinical assessment, most patients undergo ultrasound evaluation of their lower limb arteries and are then triaged into three groups. Those who are unsuitable for reconstruction or intervention require no further imaging. A small group of patients will have ultrasound findings that delineate lesions adequately enough to proceed directly to surgical reconstruction or angioplasty and/or stent placement. The third group requires further diagnostic angiography before definitive treatment.

The techniques available to us include CTA, MR angiography, and conventional catheter angiography. We perform MRA if a patient has a history of previous allergic reaction to iodinated contrast or if renal function is a concern. Again, if a Doppler examination reveals severe extensive arterial wall calcification, we generally choose catheter angiography rather than CT. This is especially true when distal runoff is to be assessed and these vessels are extensively calcified on a Doppler study. Although calf vessels can often be well visualized on CTA, evaluation is seriously compromised if the arteries are significantly calcified.

In practice, most patients undergo CTA as their angiographic imaging examination. Arterial phase timing is ensured by performing low-dose scanning in real-time at the cranial limit of the acquisition and beginning scanning when contrast is visualized in the aorta. We routinely scan from the renal arteries to the feet. To decrease radiation exposure, x-ray dose is adjusted as the scan progresses caudally.

Image interpretation is a critical component of CTA at any site in the body, but particularly in the lower limbs. A modern workstation is essential for accurate interpretation. The ability to reconstruct the images in any plane and to create MIP images is essential. The image series usually consists of more than 900 transverse images, and therefore 3D projection images are the only hard copy. Soft-copy reporting is mandatory.

Interpretation begins with a review of the abdominal organs, which frequently reveals silent but significant pathology in this aged population. Each arterial segment is subsequently interrogated on transverse and oblique projections, using interactive 3D reconstruction. We perform our reconstructions on a GE Advantage workstation (ADW4.2), which comes installed with the scanner.
Advanced software allows bone removal to further improve image quality and to display pathology to referring clinicians. The reconstructed angiographic images are discussed at multidisciplinary clinical meetings where further intervention is planned and scheduled. CTA accurately defines the varying degrees of stenosis and occlusion in the peripheral vessels. The images are further correlated with Doppler findings, which assist in determining whether the appropriate treatment is surgical or percutaneous intervention. In addition, the suitable approach for either percutaneous or surgical intervention can be planned, avoiding the need for additional angiography and decreasing contrast load at subsequent interventional procedures. As a predominantly cross-sectional imaging technique, CTA also provides information about the vessel wall. It may reveal aneurysm formation in either the popliteal or aortic segments, allowing measurement of the true diameter of aneurysms and planning for surgical or endovascular repair. It may also identify unsuspected inflammatory causes of arterial lesions and provide information about pathologies in other organs. For example, we routinely find masses in the abdomen/pelvis that may be relevant to patient management. The literature and our clinical experience suggest that with dedicated interpretation, CTA can detect more than 90% of angiographically significant lesions. This level of accuracy can increase with rigorous patient selection to exclude those with heavy arterial calcification. Most of our patients who undergo CTA have no other arterial imaging procedure before intervention. We continue to use ionizing radiation and iodinated contrast, with their associated risks. Image interpretation may be difficult in patients with extensive calcification in the vessels, especially on the angiographic images (Figure 12). This problem can, however, be overcome by evaluating these areas on the source images. The number of source images to be evaluated is large (over 700), but they are not difficult to interpret, and as experience increases, they can be interpreted within a reasonable time.

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Disclosures:

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