Assessment of Aortic Pathology and Peripheral Arterial Disease Using Multidetector Computed Tomographic Angiography

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The development of multidetector computed tomography represents a remarkable diagnostic advancement because this imaging modality has been widely used in the evaluation of the cardiovascular system. With scanner-adjusted image acquisition and contrast medium administration, multidetector computed tomographic angiography provides a cost-effective and accurate imaging assessment in patients with aortic pathologies or peripheral arterial occlusive disease. Multidetector computed tomographic angiography is associated with several advantages, including high image spatial resolution and rapid imaging acquisition speed. This diagnostic methodology allows accurate detection of a variety of intravascular lesions in the carotid artery, thoracic and abdominal aorta, renal arteries, and peripheral arterial systems. This article provides an overview of multidetector computed tomographic angiography in the assessment of arterial disease and reviews current literature about this diagnostic technology in the evaluation of aortic and peripheral arterial pathologies.

Keywords: multidetector CT angiography; peripheral arterial disease; dynamic imaging; computed tomography; thoracic aortic aneurysm

Since the technique of transcatheter digital subtraction angiography (DSA) was introduced nearly 5 decades ago, this imaging modality has been widely regarded as the gold standard in evaluating patients with occlusive disease of the aortoiliac vessels and infrainguinal arterial circulations. However, complications of this invasive imaging technique, including iatrogenic arteriovenous fistula, pseudoaneurysm, retroperitoneal hematoma, and even life-threatening access site hemorrhage, are well described and can be associated with significant morbidity. Significant technologic advances in helical computed tomography (CT) have taken place in the past 2 decades that have enabled evaluation of peripheral circulation by using a single injection of contrast material, with thinner slice sections and faster acquisition time.

The introduction of multidetector computed tomography (MDCT) in the early 1990s represents a remarkable improvement in CT imaging, particularly in the diagnostic evaluation of cardiovascular systems. Detectors are those components of a CT scanner that capture the imaging information by analyzing the x-ray beam as it passes through the body. A single-detector CT scanner has only 1 detector to capture and process imaging information. In contrast, an MDCT scanner has several detectors, thus greatly enhancing the speed of imaging processing. The first MDCT scanners had 2 detectors. In the ensuing years after its introduction, continuous advancement of this MDCT technology has led to the development from 4-, 8-, and 16-detector-row CT scanners to the current 64-detector-row CT scanners. With each new advance, the MDCT scanners...
became increasingly faster in imaging acquisition. These MDCT scanners can now acquire hundreds of images in just a few seconds.

Corresponding advances in computer hardware have kept pace with a newer generation of MDCT scanners. Advanced computer systems enable more efficient imaging-processing software, which provides more accurate diagnostic information that could not be reproduced a decade ago. Various advanced techniques to process 3-dimensional images, including maximum intensity projection or volume rendering, provide enhanced visualization of peripheral vasculature. This imaging modality has created a new diagnostic strategy in peripheral arterial circulation, with widespread clinical applications in occlusive disease, aneurysm disease, and traumatic vascular injuries.

Two important differences exist between the conventional spiral CT and MDCT. The first difference is that MDCT can acquire images at a significantly faster rate of 0.37-second rotation speed, compared with a 1-second rotation speed for the conventional CT scanner. In addition and more important, MDCT acquires volume data in contrast to individual slice data, as in the case of the conventional CT scanner. The combined effect of these 2 features enables MDCT to acquire a thin-slice imaging section with a fast scanning time, without compromising the spatial resolution of the original axial images.

The noninvasive and rapid imaging acquisition of MDCT angiography with a radiation exposure approximately 4 times less than that of the conventional transarterial DSA has gained wide acceptance from clinicians and patients. In addition, the postimaging process of MDCT angiography at high spatial resolution and consistent, high image quality renders this a reliable and observer-independent diagnostic modality in the evaluation of various vascular structures. Many clinical investigations have also validated the high diagnostic accuracy of MDCT angiography compared with magnetic resonance (MR) angiography, transarterial DSA, and duplex ultrasound in the evaluation of the peripheral vascular circulation and traumatic vascular injuries.

With an increased availability of MDCT in health care facilities worldwide, this imaging modality has been widely used in many interdisciplin ary clinical vascular practices as well as in emergency departments for patients with vascular injuries. It is a commonplace occurrence that this diagnostic modality is offered as a 24 hours a day, 7 days a week service in most tertiary hospitals. As a result, MDCT angiography has replaced transarterial DSA and become the preferred imaging study of choice in many clinical practices when patients with aneurysmal or occlusive vascular conditions are evaluated. The objective of this article is to discuss the clinical application of MDCT angiography and its relevant utility in the evaluation of various vascular systems.

Principles of Computed Tomography Angiography

Imaging processing of CT angiography encompasses the following principles: First, adequate arterial contrast enhancement by intravenous injection is achieved during CT images acquisition. Second, adequate cranial-caudal scanning of the vascular system is performed during maximal arterial contrast opacification. Third, digital image processing of the acquired data is performed using various postprocessing algorithms, which include maximum intensity projection, volume-rendering technique, surface-shaded display, and multiplanar reconstruction. Optimal evaluation of the vascular circular using MDCT angiography also requires two essential conditions: (1) maximal arterial contrast enhancement while reducing venous contrast interference to allow high-quality 3-dimensional image reconstructions and (2) high spatial resolution.

A MDCT evaluation can perform image acquisition with shorter scanning time and greater spatial resolution compared with a conventional CT scan. In a conventional single-detector CT angiography evaluation, for instance, the table speed varied from 5 to 10 mm/s. This speed could be increased to 36 mm/s using a 16-detector CT scanner. The section thickness has decreased from 5.5 mm with single-detector CT angiography to 0.75 mm with a 16-section MDCT angiography. These technologic refinements have resulted in greater imaging quality, with scans covering from the aorta to the pedal vessels with a single-bolus contrast injection. Although the faster scanning time using the MDCT system can theoretically reduce the amount of contrast medium based on a single-bolus intravenous administration, this may result in lower spatial imaging resolution and imprecision in timing acquisition.

The technical parameters of MDCT image acquisition are partly influenced by the type and the model of the multidetector scanner (ie, 4-, 8-, 16-, or
current 64-detector-row CT scanners). Even with the current technologic advancement in CT imaging, challenges remain in determining the optimal timing of arterial contrast enhancement when evaluating lower extremity arterial circulation. This challenge is partly influenced by the individual hemodynamic and physiologic status of each patient. For instance, patients with compromised cardiac output with significant obstructive disease involving the lower extremity circulation may have a substantial delay to achieve optimal contrast opacification of the pedal vessels.\textsuperscript{16} In addition, the presence of an aortic aneurysm may further contribute to the timing delay due to prolonged contrast transit time within the aneurysm. Various techniques of determining acquisition parameters based on a single contrast bolus have been described to improve the image quality and diagnostic accuracy of MDCT of peripheral arterial circulation.\textsuperscript{6,11,17,18}

**Comparison With Other Dynamic Imaging Modalities**

Various noninvasive imaging modalities, such as MR angiography, have been used extensively in evaluating patients with peripheral arterial disease.\textsuperscript{19} Compared with CT angiography, MR angiography has significantly less spatial resolution, particularly in analyzing small-caliber vessels such as the infrapopliteal circulation. In addition, scanning a large bodily segment encompassing an arterial system based on a single-bolus contrast injection to achieve optimal arterial enhancement with minimal venous opacification represents a challenge for MR angiography. However, MR angiography does have some advantages compared with CT angiography, including no ionizing radiation is used and no iodinated contrast agent is needed. To address this potential drawback, researchers have proposed methods to reduce the radiation dose required during a CT evaluation by automodulation of the milliampere dose during CT image acquisition, lower dose protocol at 50 mAs, and low kilovolt setting at 100 kVp.\textsuperscript{2,18,20} Further studies are currently underway to validate the diagnostic accuracy of CT angiography using these reduced radiation dose protocols in clinical practice.

An important drawback of MDCT angiography is the suboptimal vessel assessment in calcified arteries. Several studies have noted a decreased diagnostic accuracy of MDCT angiography in vessels with severe calcification compared with arteries without vessel wall calcifications.\textsuperscript{11,14,21} Ota et al\textsuperscript{14} reported a series of 27 cases of MDCT angiography of peripheral arterial occlusive disease. Using a stratification system based on the severity of arterial calcification, the authors reported decreased diagnostic accuracy of MDCT angiography in vessels with increased calcification.\textsuperscript{14} This diagnostic inaccuracy can lead to potential overestimation of luminal stenosis due to arterial calcification, particularly in patients with diabetes.\textsuperscript{22-24}

When patients with lower extremity arterial occlusive disease were evaluated, MDCT angiography showed comparable pooled estimates of sensitivity and specificity. Visser et al\textsuperscript{25} and associates reported a meta-analysis of gadolinium-enhanced MR angiography during a 4-year period of all patients with lower extremity arterial occlusive disease, and reported a pooled sensitivity of 97.5% and a pooled specificity of 96.2% for MR angiography, in contrast to 87.6% and 94.7%, respectively, for color-guided duplex ultrasonography.\textsuperscript{25} Koellemay et al\textsuperscript{26} similarly reported a meta-analysis which estimated a 94% sensitivity and specificity for 3D gadolinium-enhanced MR angiography.\textsuperscript{26} The advantages of MDCT angiography compared with MR angiography include relatively short imaging time, significantly greater spatial resolution, and lower cost for the MDCT evaluation.\textsuperscript{23} In vessels with a low flow state due to small vessel caliber or compromised cardiac function, the MR angiography images frequently mimic luminal narrowing or overestimate the severity of arterial disease. In addition, MR angiography is contraindicated in patients with metallic prosthesis or who are claustrophobic.

**Imaging of Carotid Arteries**

Atherosclerotic lesions of the extracranial carotid arteries account for nearly two-thirds of all ischemic strokes.\textsuperscript{27,28} Accurate evaluation of carotid arteries to determine the severity of atherosclerotic lesions is critical because appropriate intervention based on accurate lesion evaluation can lead to stroke prevention and improved survival.\textsuperscript{29,30} Although ultrasonic imaging is widely used in carotid artery screening, it is associated with certain limitations, which include inability to evaluate potential lesions in the distal carotid artery near the skull base or proximal carotid vessels near the thoracic inlet.
Because of the recent advances in carotid stenting technology, many physicians have increasingly used transcatheter DSA as an imaging modality for carotid artery lesions. However, transcatheter DSA is associated with small but potential serious complications, including catheter-related groin complications and distal cerebral embolization caused by catheter manipulation.

Before the advent of MDCT technology, helical CT angiography was commonly used for evaluating atherosclerotic lesions in the carotid arteries. However, the enhanced temporal and spatial resolution of MDCT scanners significantly improved the diagnostic accuracy of atherosclerotic disease involving the carotid artery (Figure 1). In contrast to carotid duplex ultrasound, MDCT can provide accurate evaluation of intracranial as well as extracranial carotid artery in the same setting (Figure 2). In a study that compared the diagnostic accuracy of MDCT vs intra-arterial DSA, Silvennoinen et al analyzed 73 carotid arteries in 37 patients who had carotid artery bifurcation lesions. The authors reported a remarkable diagnostic accuracy for MDCT in which the sensitivity and specificity were 75% and 96% for high-grade stenosis and 88% and 82%, respectively, for moderate carotid stenosis. Additional studies using dynamic perfusion CT angiography in evaluating the composition of atherosclerotic plaques in the intracranial circulation and hemodynamic brain perfusion similarly underscored the diagnostic value of MDCT in these lesions.

Previous studies have shown a correlation between coronary vessel calcification, as determined by CT angiography, and coronary stenosis as assessed by intra-arterial DSA. McKinney et al analyzed the correlation between calcium burden within the carotid arteries and the degree of carotid bifurcation lesion using contrast-enhanced MDCT of the neck in 61 patients. They reported a strong correlation between the amount of calcium within the vessel wall and the degree of stenosis at the internal carotid artery bifurcation. This finding confirmed a high correlation between carotid calcium scores and the severity of coronary heart disease. In addition, this study highlights a potential utility of MDCT in assessing the calcium burden of the internal carotid artery for screening purposes. However, it is noteworthy that current evidence remains scarce in correlating calcium load with any prognostic significance in patients with nonhemodynamically significant carotid lesions. By extrapolating from the coronary literature, the role of MDCT in determining the diagnostic benefit of carotid calcium burden must be addressed by multicenter studies to validate its prognostic benefit as a screening tool.
A potential diagnostic challenge of CT angiography in a carotid artery is the differentiation between total occlusion and pseudo-occlusion, which is defined as high-grade stenosis with a dramatically diminished flow that does not contribute to the perfusion of ipsilateral cerebral hemisphere. Although no intervention is required in patients with complete carotid occlusion, patients with pseudo-occlusion or string sign may require systemic anticoagulation with intravenous heparin administration and should be considered for carotid endarterectomy or stenting. Carotid pseudo-occlusion is typically difficult to diagnose with duplex ultrasound. Similarly, the diagnostic accuracy of MR angiography is limited because it frequently overestimates the severity of carotid lesions. Catheter-based DSA has long been considered the diagnostic study of choice for this condition. Recent studies, however, have revealed that contrast-enhanced MDCT provides similar diagnostic accuracy compared with intra-arterial DSA in differentiating high-grade carotid stenosis, total carotid occlusion, and carotid pseudo-occlusion.41,42

Imaging of Aortic Aneurysm and Aortic Dissection

Surgical revascularization was the mainstay of therapy in patients with aortic aneurysm or aortoiliac occlusive disease before the advent of endovascular technologies. In these patients, intra-arterial DSA was the primary imaging modality to assess the extent of aortoiliac pathologies. The development of endovascular stent graft technology has broadened the diagnostic utility of CT angiography in the evaluation of aortic disease.43 In contrast to DSA, CT angiography is undoubtedly less invasive and more accurate in determining the aneurysm diameter and assessing the mural thrombus burden, and it also enables clear visualization of the aortic wall to assess the presence of an inflammatory aortic aneurysm. In addition, CT angiography enables accurate detection of aneurysm rupture or contained leakage.

In patients with suspected acute aortic dissection, contrast-enhanced MDCT scanning of both chest and abdomen should be performed because it
is particularly useful in detecting intimal flap, the extent of aortic dissection, branch vessel involvement, patency of true and false lumens, potential pericardial effusion, and even the luminal patency of proximal coronary arteries. In this imaging modality, an initial noncontrast CT scanning should be performed to rule out intramural hematoma, because intravenous contrast may obscure this diagnosis due to uniform opacification of luminal structures. Intramural hematoma may appear as localized thickening of the aortic wall with internal displacement of intimal calcifications; alternatively, it may present as a crescent shaped, high-attenuation signal within the aortic wall.

The diagnosis of aortic dissection is established by the visualization of the intimal flap separating the true and false lumen (Figure 3). Additional CT signs that are suggestive of aortic dissection include compression of the true lumen by the false lumen, widening of aortic lumen, and displaced intimal calcification. Limitations of CT scanning include inability to identify the location of intimal tear, necessity of administering iodinated contrast agents, and difficulty in assessing aortic insufficiency.

The diagnostic importance of CT angiography in the evaluation of aortic dissection is highlighted in the International Registry of Acute Aortic Dissection (IRAD) study, in which the contrast-enhanced CT scan was the most commonly performed initial diagnostic modality in patients with suspected aortic dissection. The sensitively of CT scan for the diagnosis of acute aortic dissection was 83% to 100% and the specificity was 87% to 100%

Current diagnostic evaluation of aortic aneurysm for endovascular repair relies primarily on CT angiography to assess the anatomic suitability for endograft implantation (Figures 4 and 5). The available software program is capable of reconstructing a 3D display of aortic morphology images from thousands of CT scans, which provides an invaluable tool for preoperative planning and postoperative surveillance (Figure 6). The treatment objective of endovascular stent graft implantation is to exclude the aortic aneurysm from the systemic circulation. Computed tomographic angiography provides sensitive information regarding the presence of contrast within the aneurysm sac, or endoleak, after endograft placement. Multiple studies that have compared the diagnostic accuracy of various imaging modalities have reported that CT angiography provides greater sensitivity and specificity than conventional angiography for endoleak detection or inadequate endograft exclusion.

The success of endograft exclusion of an infrarenal aortic aneurysm is in part influenced by appropriate patient selection with suitable aortic morphology for stent graft implantation. Favorable anatomic criteria for successful aortic endograft implantation include a proximal aortic neck of 15 mm below the renal arteries, absence of aortic thrombus within the aortic neck, aortic angulations of less than 65° within the endograft landing zone, minimal iliac vessel tortuosity, and distal iliac artery neck of 15 mm for endograft implantation. Newer generation endografts, with fenestrated or branched stents, allow treatment of juxtarenal, suprarenal, or even thoracoabdominal aortic aneurysm. Because these fenestrated or branched aortic endografts are
custom made according to the individual patient’s aortic morphology, MDCT scanning with 3D image reconstruction provides critical preoperative anatomic information about visceral vessel angulations and distance from various aortic branches to allow endograft device customization.50,53

**Imaging of Renal Arteries**

The most common clinical indications of renal artery angiography are to identify renal artery pathologies, including renal artery stenosis, fibromuscular dysplasia, or renal artery aneurysm, which may be responsible for conditions such as renovascular hypertension, renal parenchymal dysfunction, or pain-related symptoms.

Renovascular hypertension caused by renal artery stenosis is a curable condition that affects approximately 5% of patients who have secondary hypertension.49 The conventional screening modality using Doppler ultrasound to detect renal artery stenosis is highly dependent on the experience of the ultrasonographer as well as the patient’s body habitus. Potential inaccuracy using ultrasound can occur when lesions are encountered in the accessory renal arteries. Compared with transarterial DSA, duplex ultrasound for detecting renal artery stenosis is associated with a sensitivity and specificity of 75% and 89%, respectively.54 Both MDCT angiography and MR angiography can be used to evaluate renal artery occlusive disease. Both imaging modalities have similar diagnostic accuracy in evaluating renal artery stenosis (Figures 7 and 8). By comparing MR angiography and MDCT angiography of renal arteries in 46 patients, Willmann et al13 reported sensitivities of 93% and 92%, respectively, and specificities of 100% and 99%, respectively.13 Despite the similar diagnostic accuracy in this study, the authors reported a higher patient acceptance for MDCT angiography due in part to potential claustrophobic effects associated with MR angiography. For
patients who received renal artery stenting, MDCT angiography can also be used for poststenting surveillance to detect potential lesion recurrence.

Another important indication to perform renal artery angiography is to evaluate the renal anatomy of live kidney transplant donors. In the latter scenario, it is important to detect any associated anatomic variance in kidney donors, including accessory renal arteries, multiple renal artery branches, or incidental renal pathology such as renal cysts. For evaluating the renal vasculature in transplant donor patients, MDCT angiography has the advantage over MR angiography in that it is more acceptable to patients and misses fewer accessory renal arteries.13

Studies that have used MDCT angiography to determine the sensitivity and specificity for the identification of accessory renal arteries have been compared with either intraoperative finding or conventional DSA as the standard. These studies reported sensitivity rates of 80% to 100%, with specificity rates of 96% to 100% in the detection of accessory renal arteries.52,55-57 The sensitivity and specificity of the identification of early arterial branching was reported as 100% by Kim et al,55 who analyzed 42 living renal transplant donor candidates by comparing MDCT angiography and MR angiography.57 Laugharne et al52 analyzed renal artery anatomy in 156 patients undergoing live donor renal transplantation and compared the diagnostic accuracy of MDCT angiography with intraoperative findings.52 The authors reported a sensitivity of 89% and a specificity of 100% using MDCT angiography compared with intraoperative findings. These studies have consistently validated the diagnostic accuracy of MDCT angiography in assessing renal vasculature.

Imaging of Aortoiliac and Lower Extremity Arterial Circulation

Duplex ultrasound evaluation and pulse volume recording with the ankle-brachial index measurement are commonly used diagnostic tools for both screening and assessing lower extremity arterial
occlusive disease; however, these noninvasive studies are associated with certain limitations. Non-compressive calcification in the lower extremity arterial system frequently overestimates arterial blood pressure and yields a suboptimal ultrasound evaluation. In addition, duplex ultrasound is operator dependent and may provide a detailed image of extraluminal pathologies, including popliteal entrapment syndrome or cystic adventitial disease of the popliteal artery.

Although conventional intra-arterial DSA remains the standard diagnostic technique for evaluating patients with lower extremity arterial occlusive disease, CT angiography is less invasive and faster, and provides a high spatial resolution that scans over a wide region of the body (Figures 9 and 10). The additional advantages of CT angiography are the detection of extraluminal pathology, including adventitial cystic disease of the popliteal artery or popliteal artery entrapment syndrome in patients whose claudication syndrome may mimic peripheral arterial occlusive disease. Multidetector CT angiography provides a detailed evaluation of eccentric lesions and permits identification of greater arterial segments, particularly in the evaluation of peripheral arterial occlusive disease. The sensitivity and specificity of MDCT angiography compared with conventional DSA are reported to be between 93% and 100% for peripheral arterial circulation.58-60

For preoperative evaluation of peripheral arterial vessel mapping of upper or lower extremities, MDCT angiography provides an alternative to duplex ultrasound or transarterial DSA evaluation. Multidetector CT angiography is accurate for arterial mapping before complex extremity revascularization or free flap reconstruction in the upper and lower extremity arteries.61,62 In a study with 14 patients, Bogdan et al61 demonstrated a 100% agreement between MDCT angiography and intraoperative findings regarding arterial anatomy in patients with complex upper extremity reconstructions. In addition, preoperative images from MDCT angiography changed the surgical approach in 2 of the 14 patients.61 In other studies that evaluated 10 patients undergoing microsurgical reconstructions of the head, neck, and peripheral upper and lower extremities, all patients underwent a preoperative MDCT angiography with 3D vascular and soft tissue image reconstructions. The authors reported that this preoperative imaging modality provided precise vessel mapping analysis for microsurgical reconstruction and was more cost-effective compared with the traditional transcatheter DSA for vessel mapping.62

Several studies have recently examined the diagnostic accuracy of 4-detector-row CT angiography in the evaluation of aortoiliac and infrainguinal arteries in patients with peripheral arterial occlusive

Figure 7. Multidetector computed tomographic angiography of the aorta and its visceral vessels in a 52-year-old man shows patent bilateral renal arteries.

Figure 8. Multidetector computed tomographic angiography of the aorta and renal branches in a 72-year-old woman shows patent bilateral renal arteries.
disease.\textsuperscript{12,22,63} Using slice thicknesses between 1.25 mm and 5 mm, 3-detector-row CT angiography yields sensitivities and specificities between 91\% and 99\%.\textsuperscript{8,10,11,14,17} However, because of limited spatial resolution in vessels with diameters less than 3 mm, technical challenges remain when 4-detector-row CT angiography is used to evaluate infrapopliteal or pedal arteries. Ofer et al\textsuperscript{11} reported 64\% (14 of 22 vessels) of all radiographic mismatches between conventional DSA and 4-detector-row CT angiography were located in small-caliber vessels, including the renal, infrageniculate, or pedal arteries. In a similar study that evaluated small-diameter peripheral arteries of the calves, Martin et al\textsuperscript{10} reported that all of the 22 infrapopliteal segments could not be adequately visualized by the 4-detector-row CT angiography. However, with the enhanced spatial resolution of the 16-detector-row CT angiography, researchers were able to achieve remarkable sensitivities and specificities of 96\% and 97\% for assessing luminal lesion in infrapopliteal and pedal vessels.\textsuperscript{7,12}

Another advantage of MDCT angiography is that image comparison of contrast opacification can be made between the peripheral venous vessel and central aortic image, thus allowing better opacification of collateral vessels or arteries distal to an occlusion segment. Ota et al\textsuperscript{14} examined 480 infrainguinal arterial segments in 24 patients and noted that 10 of these vessel segments (2\%), which were clearly identified on MDCT angiography, could not be visualized using the conventional DSA. Thee finding of this study was consistent with a similar study by

Figure 9. (A) Multidetector computed tomographic angiography shows the aortoiliac artery circulation in a 63-year-old man with buttock claudication. (B) Three-dimensional image reconstruction shows intra-arterial calcification of the aorta (large arrow) and right common iliac artery (small arrow).
Martin et al,\textsuperscript{10} who compared MDCT and conventional DSA in 35 patients with aortoiliac and infrainguinal occlusive disease. The authors reported that 91 of 105 arterial segments (86.7\%) that were inadequate by catheter-based DSA evaluation were visualized without difficulty using MDCT angiography.

With 16-detector-row CT angiography, a sensitivity higher than 94\% has been demonstrated for peripheral arterial circulation, which encompasses aortoiliac vessels, femoral arteries, infrapopliteal segments, and pedal arteries.\textsuperscript{7} On the basis of the current MDCT technologies, diagnostic evaluation using 16- or 64-detector row CT angiography can be recommended for patients with peripheral arterial occlusive disease involving infrageniculate or pedal vessels (Figures 11 and 12).

A recent meta-analysis evaluated 12 studies with more than 400 patients that compared DSA and MDCT angiography. It found the pooled sensitivity and specificity were, respectively, 92\% (95\% confidence interval [CI], 87\%-95\%) and 91\% (95\% CI, 87\%-95\%) for the aortoiliac level, 96\% (95\% CI, 94\%-99\%) and 85\% (95\% CI, 73\%-89\%) for the femoropopliteal level, and 91\% (95\% CI, 85\%-97\%) and 85\% (95\% CI, 72\%-97\%) for infrapopliteal level.\textsuperscript{15} However, there has been significant heterogeneity among the studies in terms of scanning protocol and image acquisition, which can result in potential patient selection bias for image interpretation. The authors from this report concluded that MDCT angiography has high diagnostic value compared with the conventional DSA modality.

There remains several technical challenges for CT angiography of lower extremity circulation, which include (1) incorporation of a relatively large amount of intravenous contrast (140 to 160 mL), (2) appropriate imaging acquisition speed so that it does not exceed 50 mm/s to avoid image scanning ahead of intra-arterial contrast arrival, and (3) the need for postscanning image processing for 3D image reconstruction because the large volume of images of lower leg circulation cannot be adequately viewed using axial images alone. Several recent studies have provided various imaging protocols for MDCT angiography to optimize scan enhancement and reduce the intravenous contrast requirement of lower extremity arterial evaluation.\textsuperscript{6,16,64}

\begin{figure}[h]
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\caption{Multidetector computed tomographic angiography shows the iliofemoral arterial circulation in 2 patients with lower leg claudication. (A) A 50-year-old man with an occluded right superficial femoral artery (single long arrow) with reconstituted superficial femoral artery at the level of middle thigh. Arterial calcifications (single short arrow) are shown in the bilateral distal superficial femoral arteries. (B) A 53-year-old man with occluded right common iliac artery (double arrows).}
\end{figure}
Postoperative bypass graft surveillance is a critical component of clinical care in patients who undergo peripheral vascular reconstruction, because as many as 30% of patients develop graft-related complications within the first 2 years after surgery.\textsuperscript{65,66} Duplex ultrasound has long been considered the imaging study of choice in postoperative graft surveillance owing to its low cost and wide availability. Frequently, when bypass graft lesions are detected by ultrasound, patients still undergo a transarterial angiography to confirm the lesion before undergoing corrective surgical revision.

Willmann et al\textsuperscript{8} performed a prospective study with 65 patients who underwent MDCT angiographic evaluation of 85 peripheral arterial bypass grafts.\textsuperscript{8} The authors reported that 4-detector-row CT angiography is feasible, accurate, and reliable in the assessment of peripheral arterial bypass grafts. In addition, this imaging modality is accurate in detecting graft-related complications, including stenosis, aneurysmal development, and arteriovenous fistulas.\textsuperscript{8} The authors recommended that MDCT angiography can be used to replace transarterial DSA to confirm potential bypass graft lesions as identified by the duplex ultrasound. In postoperative bypass graft surveillance scans, MDCT angiography is particularly useful in assessing the bypass graft integrity when placed in an extra-anatomic course because
this may pose technical difficulty for duplex ultrasound evaluation.

Conclusions

With continual improvement of CT technology, faster imaging modality with MDCT angiography will enable image acquisition of larger anatomic segments with greater spatial solution. Multidetector CT angiography has broadened its clinical application in peripheral vasculature, with proven diagnostic accuracy in assessing occlusive disease as well as bypass graft surveillance. The current limitation of this imaging technology relates to vessel calcification, particularly in patients with diabetes. Further refinement of this modality will result in enhancing its diagnostic utility in preprocedural planning for patients undergoing peripheral vascular interventions.

References


