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Techniques in
Vascular and
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Radiology

CT Angiography of Peripheral Arterial Occlusive Disease

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Lower extremity computed tomography angiography (CTA) is an effective, noninvasive, and robust imaging modality that is being used increasingly to evaluate patients with peripheral arterial occlusive disease (PAOD). It is important for vascular and interventional radiologists, and vascular surgeons to be familiar with the strengths and limitations, diagnostic accuracy, and practical application of lower extremity CTA. In this article, we review the technical principles of image acquisition, visualization techniques to effectively interpret the large volumetric datasets generated, and the current practical application of lower extremity CTA with respect to PAOD.
Tech Vasc Interventional Rad 9:143-149

KEYWORDS CT angiography, peripheral arterial occlusive disease

Lower extremity computed tomography angiography (CTA) can be performed with any current multiple-detector-row CT scanner without additional hardware. In general, peripheral CTA acquisition strategies follow those of abdominal CTA.[1] The patient is placed supine, feet-first on the scanner with the legs positioned at isocenter. Automated tube current modulation is recommended to individualize radiation dose and decrease image noise. Otherwise, a tube voltage of 120 kV and tube amperage of up to 300 mA is generally used. Our scanning protocol consists of (1) the digital radiograph topogram, (2) an optional nonenhanced acquisition to better visualize calcific plaques, (3) test-bolus or bolus triggering, (4) the actual CTA acquisition series, and (5) a second, optional "late phase" CTA acquisition in the event of nonopacification of distal vessels. The typical section thickness reconstructed with 8-, 16-, and 64-channel multidetector row CT (MDCT) is between 1 and 1.5 mm, which allows for accurate assessment of clinically relevant arterial branches.[2]

Altered peripheral arterial enhancement dynamics in patients with steno-occlusive disease may result in substantially delayed intravascular propagation of an intravenously injected contrast medium bolus.[2] The bolus transit speed may be as slow as 30 mm/s.[3] It is important to ensure that data acquisition is not faster than the intravascular contrast medium bolus down the peripheral arterial tree resulting in nonopacification. This can be done by selecting a low pitch and refraining from using the maximum gantry rotation speed. Out-running the bolus is extremely unlikely with a four-channel MDCT scanner, but is certainly possible with 16-channel and 64-channel MDCT scanners.[4]

Practical injection strategies for peripheral CTA should be categorized into "slow acquisitions" (table speeds 30 mm/s or slower, scan times 40 seconds or longer) and "fast acquisitions" (table speeds greater than 30 mm/s, scan times less than 40 seconds). Detailed review of scanning parameters for a wide range of MDCT scanners can be found elsewhere.[5]

In brief, a protocol for slow acquisitions is straightforward since there is essentially no risk of "out-running" the bolus. These "slow acquisitions" correspond to detector configuration settings of 4 × 2.5 mm, 8 × 1.25 mm, and 16 × 0.625 mm that translate into an acquisition speed of approximately 30 mm/s.[3] One to 1.5 g of iodine injected per second usually achieves adequate arterial enhancement for an average (75 kg) person. Body-weight based adjustments of the injection flow rate and volume are recommended, at least for those subjects who weigh more than 90 kg or less than 60 kg. For better aortic opacification and improved enhancement over time, we prefer to use a biphasic injection protocol.[4] We use a short (5 second) initial injection phase at a flow rate of 4.5 mL/s (400 mg I/mL), followed by a continued injection at 2.3 mL/s for the remainder of the duration that equals the scan-time minus 10 seconds. Of note, the total injection duration can be 5 seconds shorter than the scan time because the acquisition follows the bolus down the arterial tree.

For faster acquisitions (detector configuration settings of 8 × 2.5 mm, 16 × 1.25 mm, or 16 × 1.5 mm), which translates into acquisition speeds of 45 to 65 mm/s, we always inject for 35 seconds (5 mL/s, 370 mg I/mL). It is necessary to allow the bolus a "head start" to prevent the scan

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1089-2516/06/$-see front matter
doi:10.1053/j.tvir.2007.02.007

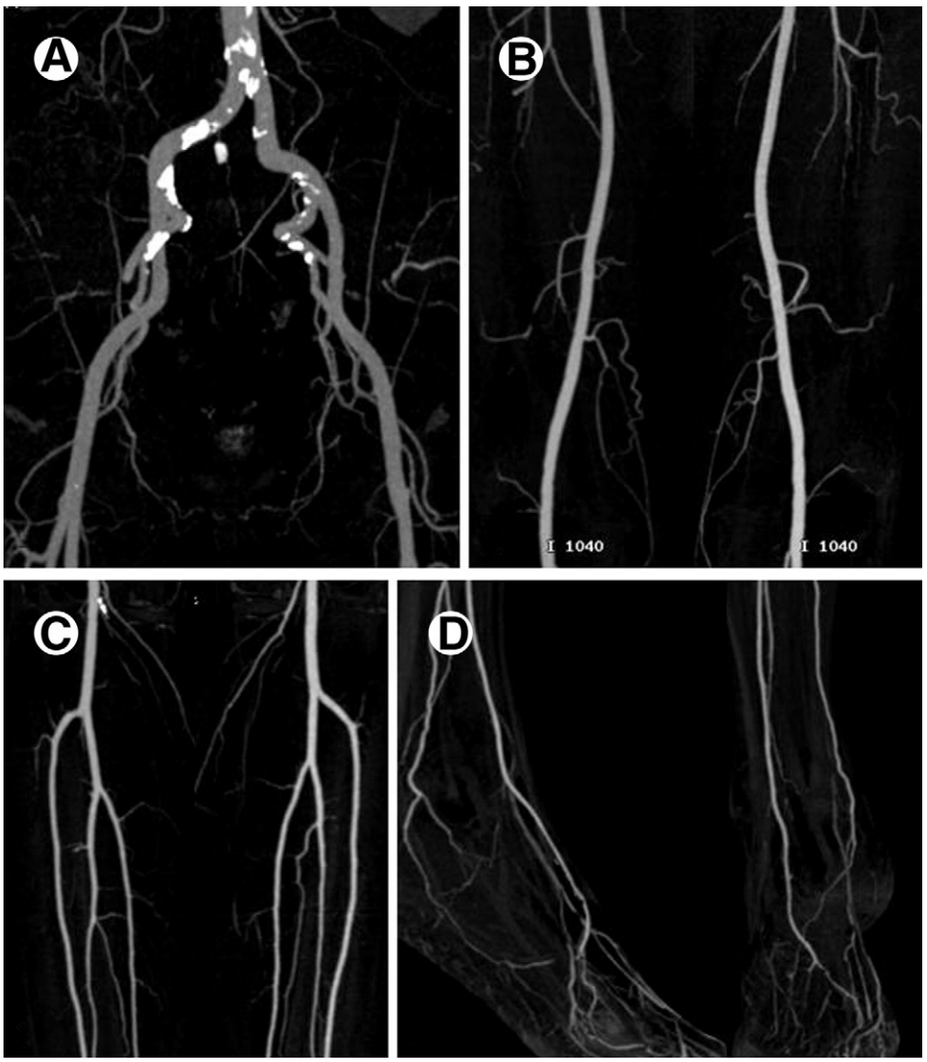

Figure 1 Visualization techniques should provide an angiographic road map for the referring and treating physician. Maximum intensity projections (MIPs) provide the most angiographic display of the vessels, and are most useful when there is little or no calcification present. (A) MIP of the inflow vessels. (B, C and D) The absence of calcification allows excellent visualization of femoral, popliteal, cruel and small vessels below the ankles.

from outrunning the bolus down the lower extremities. This is accomplished by combining a fixed injection duration of 35 seconds to fill the arterial tree with a delay of the start of the CT acquisition relative to the time of contrast medium arrival in the aorta. The faster the acquisition, the longer the diagnostic delay should be.[3] The limitation of using a very long diagnostic delay (greater than 15 seconds between contrast medium arrival time and scan initiation) is undesirable venous opacification.[4] A second CTA acquisition (covering the popliteal and infrapopliteal vasculature) can be preprogrammed into the scanning protocol. This acquisition is only initiated by the CT technologist immediately after the main CTA acquisition if he does not see any contrast medium opacification in the distal vessels.

Our injection strategy for 64-channel CT scanner has been discussed in detail elsewhere.[5]

Peripheral CTA datasets are large, consisting of over 2,000 images. Visualization, image interpretation, and effective communication can be challenging in peripheral CTA and requires a three-dimensional (3D) workstation to generate both 2D and 3D reformatted images. Because peripheral CTA is performed primarily for the purpose of treatment planning in the setting of PAOD, visualization techniques that provide an angiographic road map for the referring and treating physician are desirable (Fig. 1). Maximum intensity projections (MIP) and volume renderings (VR) both accomplish this task. MIPs provide the most 'angiography-like' display of the vasculature, and are thus ideal for communicating findings. This visualization technique is most useful when there is no or minimal vessel calcification present (Fig. 1).[5] A disadvantage of MIP is that it requires that bones are removed from the dataset, and even with the help of automated or semiautomated computer algorithms on modern workstations, this remains a time-consuming task. Additionally, inadvertent removal of vessels in close vicinity to bony structures may lead to spurious lesions.

VR preserves 3D depth information, unlike MIP, and therefore bone editing may not be required (Fig. 2). Rather, the use of volume slabs or clip planes while interactively selecting the appropriate viewing angles can be used to expose the relevant vascular segment. Interactive adjustment of the opacity transfer-function allows accentuation of vascular detail. VR is the ideal tool for fast interactive exploration of peripheral CTA datasets.

The main limitation of both MIP and VR is that calcified plaque, diffuse vessel wall calcification and endoluminal stents may completely obscure the vascular flow channel. These high attenuation foci can "shine through" the vessel,