MR angiography illustrates runoff in diabetic patients

May 01, 2008 | MRI [1]
By Karl-Friedrich Kreitner, MD [2]

Preoperative failure to identify vessels that could be recanalized or used for graft anastomosis may result in unnecessary amputations

Foot complications associated with diabetes are the most common cause of nontraumatic lower extremity amputations in the industrialized world. Research indicates that the risk of lower limb amputation is 15 to 46 times higher in diabetic patients than in those without the disease.¹ Common risk factors include peripheral neuropathy, structural foot deformity, infection, ulceration, and peripheral arterial occlusive disease.

Diabetic patients are four times more likely than the general population to develop peripheral arterial occlusive disease. This condition typically spares the proximal vessels in diabetic patients and mainly affects the more distal arteries in the calf with long-segment obstructions. These lead to rest pain, ischemic ulcers, toe gangrene, and osteomyelitis (Figure 1). Diabetic patients are consequently five times more likely to develop critical limb ischemia than the nondiabetic population.¹-³

Surgical revascularization in patients with lower limb ischemia requires precise preoperative imaging of the peripheral vessels. The ultimate aim is to reduce the rate of foot amputations in these patients. The outcome of distal bypass or intervention is greatly affected by the presence or absence of adequate pedal outflow.

Identification of distal vessels in the foot, including the pedal arch, is crucial when planning advanced distal revascularization.²-⁴ Failure to identify vessels that could be recanalized or used for a distal graft anastomosis may result in unnecessary amputations. Preoperative imaging must provide a sufficiently detailed depiction of the pedal arteries.

The main options for noninvasive imaging are contrast-enhanced MR angiography and contrast-enhanced multislice CTA. MRA offers certain advantages over CTA. Patients are not exposed to ionizing radiation or to potentially nephrotoxic iodinated contrast media. The use of iodinated contrast may be a concern for certain elderly patients with critical limb ischemia and associated renal insufficiency.

Just a few studies have compared the accuracy of contrast-enhanced pedal MRA with digital subtraction angiography.⁴-⁸ Our own study involving 24 diabetic patients demonstrated that pedal arch vessels were identified significantly more often on MR angiograms (22 feet) than on DSA images (nine feet) (Figure 2).⁵ The dedicated contrast-enhanced pedal MRA protocol showed patent pedal vessels not revealed by DSA in nine out of 24 patients (38%). Changes were made to seven patients' treatment plans: Two patients received a pedal bypass graft instead of amputation, and five patients underwent femoropedal bypass grafting instead of femorocrural or femoropopliteal bypass grafting.

Dorweiler et al considered the effect of grafting to DSA-occult pedal vessels, rather than grafting to vessels visible on DSA. They concluded that the long-term performance of grafts to vessels not visible on DSA was not impaired.⁴ Contrast-enhanced pedal MRA was found to be a meaningful adjunct in patients for whom detection of a distal target vessel suitable for bypass grafting would lead to limb salvage rather than major amputation. This applied particularly to diabetic subjects. Contrast-enhanced MRA also depicted significantly more pedal vessel segments than did DSA in a study by Hofmann et al.⁶ The technique proved superior in predicting an appropriate distal site of graft anastomosis.

A study of 35 consecutive patients with peripheral arterial venous disease, conducted by Cronberg et al, found contrast-enhanced MRA to be 92% sensitive for the detection of significant stenosis in the crural and pedal vessels.

The specificity, however, was only 64%.⁷ A total of 20/129 vessel segments were classified as normal on MRA, but they were considered to harbor either a significant stenosis or occlusion on DSA. The researchers concluded that while contrast-enhanced MRA can be considered as a useful
diagnostic adjunct, it should not replace DSA as a standard of reference. **CONTRAST TECHNIQUES**

A basic limitation of contrast-enhanced pedal MRA is the restriction of coverage to a single anatomic area. A complete peripheral runoff study requires the arterial tree to be imaged from the infrarenal aorta down to the pedal vessels. Techniques have been developed to achieve this coverage. Multistation acquisition of peripheral arteries is possible with high-performance gradient systems, ultrafast 3D sequences, automatic movement of the patient table, optimized 3D volume placement with flexible choice of scan parameters, and the availability of dedicated multichannel phased-array coils.

Problems could potentially arise with bolus chase techniques. The assessment of crural arteries may be limited due to early filling of adjacent veins. This is strongly accentuated when cellulitis and diabetic ulcers shorten the arteriovenous transit time of the contrast. Venous enhancement could even occur before the filling of the distal arteries. Venous compression is unlikely to be helpful in such cases, particularly if the patient has critical limb ischemia and a severely restricted arterial blood supply. The other main issue with bolus chase techniques is that coronal acquisition of crural arteries does not always include the pedal arteries.

The optimal approach for delineating the entire peripheral vasculature seems to be a hybrid dual-bolus approach. The cruropedal arteries are acquired first using sagittal slabs and a time-resolved acquisition technique. This allows continuous access to the calf and pedal arteries and may lessen the incidence of partial-volume artifacts in the slice direction. Two- or three-station bolus chase MRA should follow next, enabling assessment of the aorto-iliac, femoropopliteal, and proximal calf vessels.

An evaluation of this dual-bolus approach found that the cruropedal arteries could be displayed with excellent or good image quality in 95% (205/216) of cases. Venous overlay was absent in 94% (203/216) of cases. The sensitivity of this technique ranged between 80% and 100%, compared with DSA. Specificity varied from 93% to 100%.

The lack of venous overlay when using a hybrid angiography technique has been confirmed in a study of 19 patients with critical limb ischemia. A further study of 53 patients, which involved parallel acquisition, showed the dual-bolus approach to be robust. An investigation involving 31 patients found the sensitivities and specificities for the detection of peripheral artery obstructions to range from 90% to 96% and 98% to 99%, respectively. Agreement with DSA was substantial (k-values between 0.88 and 0.98). Implementation of hybrid MRA led to changes in seven patients' treatment plans. These changes were due to the detection of patent infrageniculate arteries that were not seen on DSA images. Researchers in a later study labeled a significantly higher number of calf and foot segments as diagnostic when using time-resolved MRA instead of a standard bolus chase MRA protocol. Contrast-enhanced pedal MRA can be performed routinely in patients after bypass grafting. Vessel imaging may be supplemented by soft-tissue imaging for the delineation of associated inflammatory and necrotic complications and Charcot's osteoarthritis in the diabetic foot (Figure 3). Pedal soft-tissue enhancement is a common finding on time-resolved MRA of the feet that may be used to identify sites of subclinical pedal soft-tissue injury. Diabetes can be regarded as a disease with systemic manifestations. Hybrid bolus chase MRA may be replaced by whole-body MRA in these patients. Techniques used for whole-body MRI are being improved by the introduction of time-resolved protocols and data acquisition with a continually moving table.

Implementation of new MR sequences and parallel acquisition techniques means that submillimeter 3D data sets can be acquired in just a few seconds. MRA images with perfect arterial enhancement can be attained without bolus-timing. The rapid succession of 3D data sets allows the assessment of flow and function. If you need only a few seconds for acquisition of a 3D data set, and if you repeat it several times, then you obtain some kind of 4D image that delivers some information on flow.

These protocols for whole-body MRA may, in the future, be complemented by cardiac and brain MRI. The result will be disease-specific whole-body imaging. For this to be possible, however, multiple coil systems, receiver channels, and parallel imaging techniques will be required to ensure sufficient temporal and spatial resolution.

**References**


Dr. Kreitner is an assistant professor and staff radiologist in the department of diagnostic and interventional radiology at Johannes Gutenberg-University in Mainz, Germany.

Disclosures:


Links: