Novel, non-gadolinium-enhanced magnetic resonance imaging technique of pedal artery aneurysms

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Non-gadolinium-enhanced magnetic resonance angiography (nMRA) is a noninvasive, contrast-free imaging modality used for visualizing pedal arterial anatomy. We report application of the nMRA technique for detailed arterial imaging in a patient with dorsalis pedis aneurysm. Compared with digital subtraction angiography, we demonstrate that nMRA provides sufficient arterial detail needed to develop a complex operative plan before vascular intervention without risk of contrast agent or ionizing radiation exposure. (J Vasc Surg Cases and Innovative Techniques 2017;3:87-9.)

Intra-arterial digital subtraction angiography (DSA) has long been the reference standard for arterial imaging by presenting excellent spatial resolution and artery-to-background contrast. Although DSA is considered safe, renal function impairment secondary to iodinated contrast agent exposure constrains the use of DSA in many patients with underlying renal dysfunction.[1,2] Gadolinium-based magnetic resonance angiography (MRA) has been increasingly used as a noninvasive alternative; however, gadolinium-enhanced MRA involves the risk of nephrogenic systemic fibrosis and venous image contamination in the pedal arteries because of the short arteriovenous transit time.[3-6] A novel non-gadolinium-enhanced MRA (nMRA) technique that visualizes small-vessel arterial anatomy without the use of intravascular contrast material was developed.[7,8] This technique uses velocity-selective (VS) magnetization preparation pulse, which highlights relatively fast velocity spins (eg, arterial blood) while suppressing stationary spins, creating positive angiographic contrast in a single scan. This technique, referred to as VS-nMRA, has shown promise in renal and proximal peripheral vascular imaging, given the noninvasive nature and lack of administration of contrast material. We report our first application of the technique for pedal angiography.[7,8]

CASE REPORT

Our patient was a 71-year-old woman with a medical history of hyperlipidemia and previous dorsal resection of a bone prominence on the left foot. She presented to her podiatrist with a dorsal foot mass and underwent aspiration for a presumed ganglion cyst. On aspiration of blood, she was referred to a vascular surgeon for further management.

After Doppler ultrasound evaluation demonstrated pulsatile flow in the lesion, VS-nMRA was performed in the patient using a 1.5T whole-body scanner with a quadrature foot receive coil. By use of electrocardiography cardiac gating and an appropriate cardiac trigger delay, the VS preparation pulse was synchronized to the midsystolic phase. The VS pulse had a cutoff velocity of 1.5 cm/s (ie, the signals of tissues moving slower than this threshold are suppressed) with selectivity aligned along the long axis of the foot. A three-dimensional balanced steady-state free precession acquisition was used immediately after the VS preparation pulse to further enhance blood-to-background tissue contrast.[9] The total scan time was 8 minutes, including 3-minute scout scans for localization and flow measurements and 5-minute VS-nMRA scan. The three-dimensional foot angiogram was reconstructed off-line in a desktop workstation with maximum intensity projection images generated by a homemade software written in MATLAB (MathWorks Inc, Natick, Mass). Block consent was obtained by institution protocol for use of any radiographic or intraoperative photographs with publications.

Fluoroscopic DSA imaging of the left foot revealed a dorsalis pedis aneurysm with an incomplete plantar arch due to absence of posterior tibial artery collateral vessels (Fig 1, *A*). Representative images of VS-nMRA formatted at a similar orientation (Fig 1, *B*) and in a coronal view (Fig 1, *C*) demonstrated high image fidelity with the DSA findings. The patient underwent resection of the aneurysm with reconstruction of the 2.5-cm dorsalis pedis artery defect by reversed saphenous vein autograft (Fig 2). Pathologic examination confirmed aneurysm formation. Postoperatively, Doppler signals were maintained in all digital arteries, and the patient was discharged home on postoperative day 3 in a dorsiflexed short leg splint. At follow-up, her foot was well perfused with a healed incision, no recurrent mass, and capillary refill <2 seconds in all of her toes.

DISCUSSION

Appropriate preoperative planning increases the likelihood of a technically successful operation. Safe, detailed,

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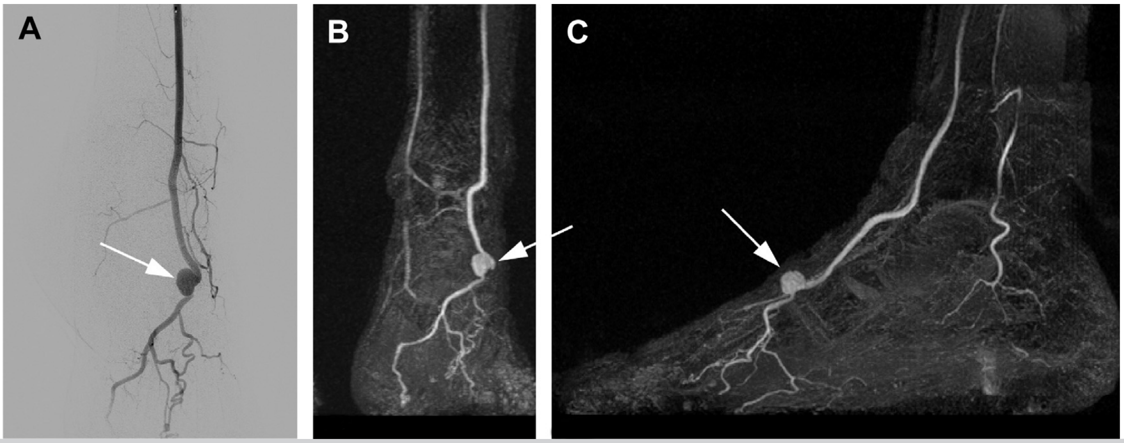

Fig 1. Digital subtraction angiography (DSA) of the left foot **(A)** showing dorsalis pedis aneurysm (*arrow*). The maximum intensity projections of three-dimensional magnetic resonance images formatted at a similar orientation **(B)** and at a coronal orientation **(C)** clearly identify the aneurysm.

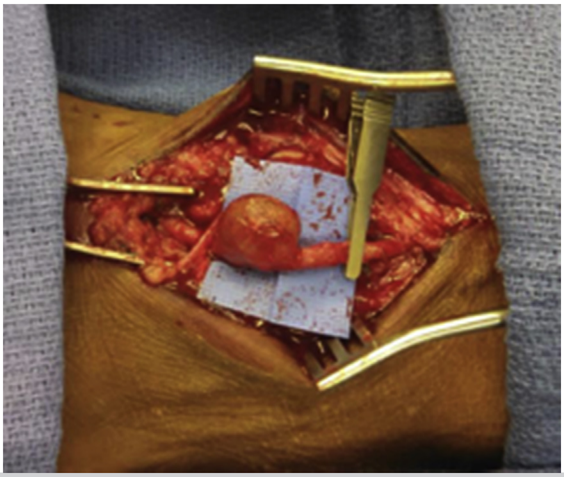

Fig 2. Intraoperative identification of dorsalis pedis aneurysm during the dorsalis pedis aneurysmectomy and saphenous vein graft reconstruction.

noninvasive imaging provides surgeons with the means to safely plan and execute more complex reconstructions with less perioperative morbidity. The presented VS-nMRA allows noninvasive, radiation- and contrast-free, high-resolution imaging of the pedal arteries. This technique presents fewer risks to the population of patients who have high risk of periprocedural complications. Because of the lack of ionizing radiation and contrast agents, imaging can be repeated with impunity, allowing renal failure patients to undergo postprocedural imaging with greater imaging detail than with duplex ultrasound evaluation without the risk of renal injury. The use of VS-nMRA is limited only in the presence of the standard contraindications to magnetic resonance imaging (MRI), such as metallic implants and severe claustrophobia.

One of the important parameters to be optimized in our nMRA protocol is associated with the one-dimensional selectivity in the VS pulse. Single-dimension selectivity may cause signal loss in vessel segments oriented orthogonal to the long axis. Acquiring data sets by running the magnetic resonance with the direction of velocity selectivity set to each of the three orthogonal directions and combining them would mitigate signal loss. Use of parallel imaging would compensate for the increased scan times needed to complete multiple orthogonal imaging sequences.

Alternative nMRA methods have been available commercially and experimentally. Time of flight is the most established approach, often used for imaging carotid and cerebral arteries; however, time of flight does not work well in the lower extremities because of the well-known issue of saturation of in-plane or slow arterial flow.[10] Quiescent-interval single-shot imaging is an inflow-based approach that has demonstrated high diagnostic accuracy in detecting stenosis in the pelvis through the calf.[11] However, its use for foot applications is deemed challenging because of slow arterial flow, particularly in patients with underlying proximal flow-limiting lesions. The nMRA method that has produced the most promising results in the foot is based on subtraction between a reference image and a blood-suppressed image obtained using flow-sensitive dephasing preparation.[12,13] However, the need for the acquisition of two images remains a drawback, which increases scan time and motion sensitivity.

Noninvasive imaging modalities other than MRI are available for evaluation of peripheral artery disease. Color duplex ultrasound is often used as the first-line screening tool, but it is highly operator dependent and relatively challenging to use in pedal arteries. Computed tomography angiography has been routinely used as it offers excellent luminal anatomy as well as vessel wall condition, such as plaque hemorrhage and calcification. The VS-nMRA presented in this report provides only morphologic information of the lumen. Flexibility of image contrast in MRI enables additional measurements of phase-contrast flow mapping, blood vessel wall imaging, and vascular calcification imaging.[14-17] These applications have been largely used for research purposes but have great potential for further improving characterization of arterial disease. As demonstrated in Fig 1, VS-nMRA could have been singularly used for preoperative planning while avoiding contrast-induced nephropathy and angiography access site complications. This particular imaging technique can be performed on GE or Siemens MRI instruments without the purchase of special coils, allowing easy integration into existing facility imaging protocols.

CONCLUSIONS

The use of VS magnetization-prepared nMRA provides the vascular surgeon with a noncontrasted, radiation-free imaging modality with outstanding anatomic and spatial relationship detail needed to plan complex vascular reconstructions in the distal extremity. This method of imaging should be strongly considered in a patient with underlying renal dysfunction requiring preoperative image acquisition.

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