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Magnetic resonance imaging characteristics of lesions relate to the difficulty of peripheral arterial endovascular procedures

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ABSTRACT

Objective: Limitations with current peripheral arterial imaging modalities make selection of patients for percutaneous vascular interventions difficult. The purpose of this study was to determine whether a novel preprocedural magnetic resonance imaging (MRI) method can identify lesions that would be more challenging to cross during percutaneous vascular intervention.

Methods: Fourteen patients with peripheral arterial disease underwent MRI before their intervention. A novel steady-state free precession flow-independent magnetic resonance (MR) angiogram was used to locate lesions, and an ultrashort echo time image was used to characterize hard lesion components including calcium and dense collagen. Lesions were characterized as hard if ≥50% of the lumen was occluded with calcium or collagen (as determined by MR image characteristics) in the hardest cross section within the lesion. The primary outcome was the time it took to cross a guidewire through the target lesion. The secondary outcome was the need for stenting.

Results: Of 14 lesions, 8 (57%) were defined as hard and 6 (43%) were soft on the basis of MR image characteristics. Hard lesions took significantly longer to cross than soft lesions (average, 14 minutes 49 seconds vs 2 minutes 17 seconds; $P = .003$). Hard lesions also required stenting more often than soft lesions (Fisher exact test, $P = .008$). Of 14 lesions, 2 (14%) could not be crossed with a guidewire, and both lesions were hard. MR images also detected occult patencies and noncalcified hard lesions that could not be seen on X-ray angiography.

Conclusions: MRI can be used to determine which peripheral arterial lesions are more difficult to cross with a guidewire. Future work will determine whether MRI lesion characterization can predict long-term endovascular outcomes to aid in procedure planning. (J Vasc Surg 2018;67:1844-54.)

The management of peripheral artery disease is limited by current imaging modalities. Physicians cannot make informed decisions about peripheral revascularization strategies because clinical imaging modalities cannot accurately evaluate important anatomic features of peripheral arterial lesions. X-ray imaging with digital subtraction angiography (DSA) remains the "gold standard" for peripheral artery disease,[1] even though it is a lumenography technique that does not image the vessel wall or visualize total occlusions. X-ray angiography can detect only extensively calcified vessel walls (occupying three or four quadrants of the vessel) with a sensitivity of 60% to 80%.[2] In addition, X-ray imaging cannot discern the morphology of calcium, even with orthogonal views, and this is an important feature that determines endovascular outcomes.[3] Cross-sectional imaging with

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computed tomography angiography (CTA) can define calcium morphology in medium-sized vessels but often cannot accurately evaluate tibial vessels because of calcium blooming. CTA also relies on flow enhancement with administration of contrast material, which is challenging to time in distal occlusive vessels with slow-flowing blood. CTA with runoff is nondiagnostic in 17% to 52% of infrapopliteal studies,[4] yet runoff is a recognized predictor of endovascular success.[5,6] Duplex ultrasound can visualize some features of the vessel wall and provides physiologic flow information, but it suffers from calcium acoustic shadowing, variable quality, user dependence, and limited field of views for procedure planning. Many physicians do not feel confident in making therapeutic decisions on the basis of ultrasound alone[7] and often order additional investigations.[7]

Not all lesions are amenable to endovascular treatment, but predicting this in advance is currently impossible. The Bypass versus Angioplasty in Severe Ischaemia of the Leg (BASIL) trial reported a 20% immediate technical failure rate for peripheral angioplasty, and most immediate failures were due to the inability to cross the lesion with a guidewire.[8] Patients with favorable anatomy, vein, and comorbidities may benefit from bypass surgery instead. Bypass surgery may even confer a survival benefit after 2 years.[9] In the absence of informed decision-making, physicians often rely on an "endovascular-first" strategy and reserve surgery for patients who fail to respond to endovascular treatment. The appropriateness of this approach is debated, and no consensus has been reached.[1,10] The main criticisms of the endovascular-first approach include the increased number of procedures, the delay in definitive revascularization, and the potential to have worse outcomes with secondary bypass after endovascular failure.[11-14]

The critical need for better selection of patients motivated the development of a new magnetic resonance imaging (MRI) method to characterize peripheral artery lesions. This method is flow independent, does not require exogenous contrast agents, and has no associated radiation. In addition, this diagnostic test can differentiate the mechanical properties of peripheral artery lesion components and was validated with histology and guidewire puncture force testing[15] in previous studies. The purpose of this study was to determine whether MRI lesion characteristics relate to immediate endovascular procedural outcomes. Our hypothesis is that MRI-defined hard lesions would take longer to cross with a guidewire compared with MRI-defined soft lesions. Our secondary hypothesis is that MRI-defined hard lesions would require stenting more often.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center retrospective cohort analysis
- **Take Home Message:** In 14 patients undergoing a peripheral endovascular intervention, those arterial lesions defined by magnetic resonance imaging as hard required longer guidewire traversal times and had a higher incidence of stenting than lesions defined as soft.
- **Recommendation:** This study suggests that magnetic resonance imaging may be a useful tool in the planning of peripheral artery endovascular interventions.

METHODS

Characteristics of the patients

Fourteen patients (mean age, 68 ± 11.6 years; 12 men) underwent lower limb endovascular revascularization at the Sunnybrook Health Sciences Centre (Toronto, Ontario, Canada). The majority of interventions were in the superficial femoral artery (SFA; 10/14 [71%]), but popliteal (3/14 [21%]) and tibial (1/14 [1%]) interventions were included as well. Most patients had critical limb ischemia, and 4 of 14 (29%) had claudication. Characteristics of the patients were typical for this subgroup; most had diabetes (11/14) and smoking history (12/14) and were taking medication for hypertension (12/14) and dyslipidemia (11/14). All 14 patients provided written, informed consent. The Sunnybrook Health Sciences Centre Research Ethics Board approved this study.

MRI

Each patient underwent MRI before the endovascular procedure. On the day of the procedure, patients were imaged with a 3T MRI scanner using a 32-channel cardiac array coil placed around the legs. The patients were imaged with two sequences. First, a flow-independent magnetic resonance (MR) angiogram was taken to locate lesions using a three-dimensional (3D) steady-state free precession (SSFP) sequence with the following parameters: field of view, 24 × 24 × 24 cm; image resolution, 1 × 1 × 1 mm; repetition time (TR), 5.54 milliseconds; echo time (TE), 3.58 milliseconds; flip angle, 45 degrees; number of averages, 1; acquisition time, 2 minutes. A novel binomial 1-2-1 water excitation pulse was designed by adjusting the phase and off-resonant frequency of the subpulses to achieve effective fat suppression while reducing the TR for faster acquisition.[16]

To further characterize the hard components of the lesion, 3D ultrashort echo time (UTE) imaging was performed using a prototype 3D cones sequence from GE Healthcare (San Diego, Calif) with the following parameters: field of view, 18 × 18 × 10 cm; image resolution, 1 × 1 × 1 mm; TR, 10 milliseconds; TE_1, 30 μs; TE_2, 2.25 milliseconds; flip angle, 9 degrees; number of averages, 1; acquisition time, 5 minutes. The second echo time was chosen to be 2.25 milliseconds to account for the fat-water chemical shift at 3T to enable effective subtraction in an effort to highlight only short-T2 signal components.