Spiral Coronary Wall Imaging: Patient Studies

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Introduction
Directly imaging the coronary wall noninvasively is an important goal in cardiovascular imaging. Major progress has been made in the development of coronary MR angiography using bright-blood techniques. We and others have developed techniques for black-blood imaging of the coronary wall.1-5 Here we report our initial results with spiral coronary wall imaging in patients.

Methods
The coronary wall imaging sequence is based on the interleaved spiral k-space trajectory technique and is composed of 1) double-inversion preparation, 2) spectral-spatial excitation, and 3) spiral readout.2 The double-inversion preparation nulls the blood signal, but can also be turned off to provide bright-blood angiographic images. Separate water- and fat-selective spectral-spatial pulses yield water and fat images to show the coronary wall and surrounding epicardial fat, respectively. Interleaved 2D spiral readouts provide an in-plane spatial resolution of 0.5-0.8 mm in a single breath-hold.

Eight patients (4M:4F, mean age 56), having undergone x-ray coronary angiography, were studied. All were over 21 years old without contraindications to MRI and provided informed consent under an approved protocol of the Stanford University Human Subjects Committee. All scanning was performed on a GE 1.5-T Signa system equipped with high-performance gradients (40 mT/m, 150 mT/m/ms). A standard 5-in. surface coil was used for signal reception. A real-time interactive imaging system was used to identify linear coronary artery segments and prescribe orthogonal scan planes for subsequent high-resolution cross-sectional imaging.6 Sequence parameters: FOV 20-24 cm, 14-20 interleaves, TI 280-350 ms, spatial resolution 0.5-0.8 mm, slice thickness 7-10 mm, flip angle 90 degrees.

Results
Figure 1 is a bright-blood image of a patient's right coronary artery (RCA) demonstrating a moderate proximal stenosis (arrowhead) and a diffusely diseased mid vessel with normal lumen size (arrow). The cross-sectional image of the mid-RCA (Fig. 2) demonstrates the normal lumen caliber, but it is surrounded by an abnormal area of gray or mottled signal indicative of coronary plaque. This is shown clearly in the corresponding coronary wall image (Fig. 2). At the site of the proximal stenosis (Fig. 3), the lumen appears smaller and irregular and the wall thickness is greater. Figure 4 shows the RCA in a patient with diffuse, but non-flow-limiting atherosclerosis. The coronary wall image shows concentric thickening.

Discussion
We have demonstrated, in patients, a flexible spiral sequence capable of rapidly and noninvasively imaging the coronary wall with high spatial and temporal resolution. The major limitation of this sequence, given the very short spiral readouts, is SNR. Coronary wall imaging by MRI is more challenging than coronary MRA, due to both the smaller size of the vessel wall than the lumen and the lack of flow enhancement of the signal. Several alternative techniques have been studied, primarily using fast spin echo in combination with either breath-holding3 or navigator-based respiratory compensation.1,4,5 Fast-spin echo can provide good SNR, but long echo trains can contribute to temporal blurring. Navigator techniques allow signal averaging to improve SNR, but may be more sensitive to blurring as the navigator acceptance window is typically several mm. Initial clinical results with these methods have been promising, demonstrating significantly greater coronary wall thickness in coronary disease patients than in normals.3

Coronary wall imaging may complement coronary MRA and help predict clinical risk, particularly if further improvements allow coronary plaque characterization.

In summary, spiral coronary wall imaging achieves high spatial and temporal resolution and can detect coronary wall abnormalities in patients. It is a promising component to a comprehensive MRI examination of coronary artery disease.

References