3D SPACE MR imaging of Human Atherosclerotic Femoral Artery at 3.0T

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Introduction:

Peripheral artery disease (PAD), affecting approximately eight million people in the US, is a condition that causes poor circulation in the legs. Magnetic resonance imaging (MRI) could be used for the noninvasive assessment of atherosclerotic plaque burden in the peripheral circulation. Typically 2D dark blood turbo spin-echo (TSE) techniques are used for femoral arterial wall imaging [1]. However, 2D techniques require prolonged imaging time to cover a large region of interest in the leg. Recently, variable-flip-angle 3D TSE T2-weighted (SPACE) has been introduced as a dark blood technique for fast imaging of vessel wall [2] at 1.5T. The purpose of our study was to evaluate the potential of this technique for assessing atherosclerotic disease of the superficial femoral artery (SFA) at 3.0T.

Materials and Methods:

Imaging: 15 healthy volunteers and 10 patients (ankle-brachial index: 0.3-0.8) underwent MR scans on a 3.0T scanner (Tim Trio, Siemens, Erlangen, Germany) using a body phased array coil. SPACE imaging parameters were as follows: 1) for volunteers, coronal acquisition covering both SFAs, TR/TE = 1600/173 ms, number of averages = 2, number of slice = 72, FOV = 380 x 380 mm^2, turbo factor = 83, resolution 0.72 x 0. 72 x 0.72 mm^3, TA = 11.4 min; 2) for patients, sagittal acquisition with only one low-ABI SFA covered, TR/TE = 1600/153 ms, number of averages = 2, slice thickness = 0.72 mm, FOV = 380 x 190 mm, turbo factor = 73, resolution 0.72 x 0.72 x 0.72 mm^3, TA = 8 min. After multi-planar reformatting (MPR) of 3D images to obtain cross-sectional orientations, 2D T1-, T2-, and PD-weighted multi-slice black-blood TSE acquisitions with inflow/outflow saturation bands were run with 7 interleaved slices (3 mm thickness, 100% interslice gap) per acquisition and a total of 10 acquisitions to cover 380 mm of SFA [1]. Image resolution was 0.52 x 0.52 x 3 mm^3. Analysis: Cross-section images of SFA were reconstructed from 3D data by MPR. For volunteers and patients, each pair of 2D axial slices of 3D SPACE and 2D TSE were analyzed using ImageJ (version 1.37v, NIH, USA) to measure signals of vessel wall, lumen and air. Wall SNR efficiency ($SNR_{eff} = \frac{SNR\sqrt{N}}{VOXEL\sqrt{TA}} = \frac{SNR}{VOXEL\sqrt{TA_{SLICE}}}$, where N is the number of imaging slices, VOXEL is voxel volume, TA is the total imaging time) and wall-lumen CNR efficiency ($CNR_{eff} = \frac{CNR\sqrt{N}}{VOXEL\sqrt{TA}} = \frac{CNR}{VOXEL\sqrt{TA_{SLICE}}}$) were compared between 2D and 3D scans. Statistical comparison was performed by means of a student t-test was used for statistical analysis.

Results:

A sample image obtained from a volunteer is shown in Fig.1. In volunteers, the signal performance of SPACE was significantly higher than that of T2-weighted 2D TSE (wall SNR_{eff}: 313.86 ± 27.83 vs. 97.41 ± 21.58, $p < 0.05$; wall-lumen CNR_{eff}: 165.69 ± 32.13 vs. 37.35 ± 28.56, respectively, $p < 0.05$). For 10 acquisitions of 2D multi-slice T2-weighted scan, around 38.6 minutes are required for coverage of SFA. A major advantage of 3D SPACE is a much shorter imaging time (11.4 minutes) to cover the same area. SFA images of a PAD patient are shown in Figure 2. 3D MPR of the whole SFA in a longitudinal view revealed extensive plaque burden (Fig. 2a). The corresponding cross-sectional SPACE (Fig. 2b, created by MPR) and TSE (Fig. 2c, d) images of the diseased SFA wall showed luminal narrowing.

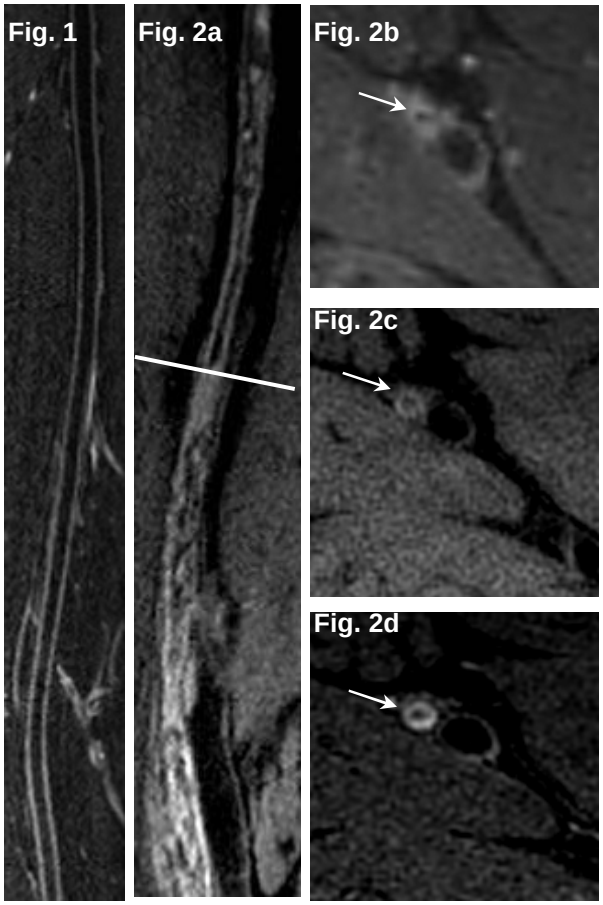

Fig.1. Healthy volunteer: MPR of longitudinal view of SFA acquired using SPACE, which shows very clear vessel wall and lumen. Fig.2. a. MPR of SPACE shows a longitudinal view of SFA with extensive plaques, b cross-sectional MPR image (from line mark on Fig. 2a). Fig2 c, d, is 2D TSE T1, T2-weighted image, respectively. All of cross-section images show the plaque of wall and lumen (arrow)

Discussions and conclusion:

The results showed that 3D vessel wall imaging of the SFA with the SPACE technique is feasible. In patients, isotropic-resolution SPACE images, with the aid of MPR, showed plaque in any orientation which is not possible with 2D TSE. This is particularly true along the vessel long axis, which provides an overview of wall morphology and plaque burden. In addition, SPACE imaging was much more time efficient as compared to 2D multislice TSE (3D vs. 2D, 11.4 vs. 38.6 minutes) and allowed for an adequate spatial coverage of the SFA with high resolution in a relatively short scan time.

References: [1] Isbell DC et al.; J Cardiovasc Magn Reson. 2007; 9:71-76. [2] Chung et al.; Proc 14th ISMRM, p. 653, 2006.