High Resolution 3D Imaging of Aortic Wall using Dark Blood TrueFISP

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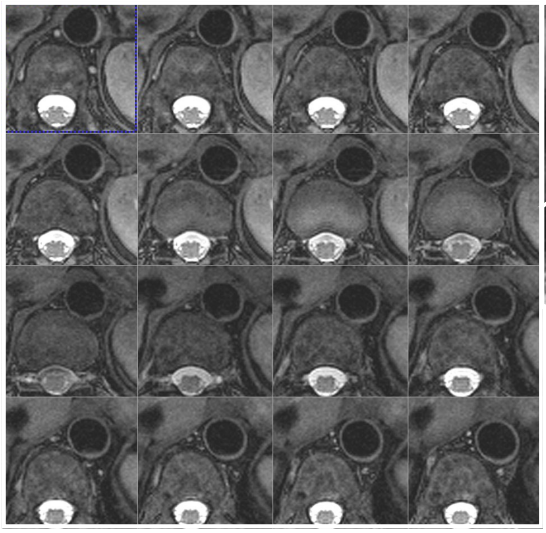
Introduction MRI of atherothrombotic plaques is important for the in vivo identification of vulnerable plaques [1]. MRI is typically performed using TSE and its variants with T1, T2 and PD weighting [2]. However, the scan time for the TSE technique is long, and the slice thickness and volume coverage are sub-optimal for 3D visualization. TrueFISP, on the other hand, provides higher sampling efficiency, and can easily be adopted for 3D imaging. We show here how 3D trueFISP, when properly prepared for fat and blood suppression, can be used to image a 40 mm segment of the aorta in 3 – 4 min with slices as thin as 2 mm. The multiple slabs of one study may then be combined to visualize a larger region of the aorta in 3D using standard software.

Method Cardiac triggered 3D trueFISP with centric reordering was used. Dual inversion dark blood preparation was applied with TI = 400–480 ms before data acquisition during each heartbeat, and 45-67 lines were collected in diastole (both TI and lines per heart beat depends on heart rate). A fat sat pulse is applied, followed by 20 RF pulses with linearly increasing flip angles to drive spins to steady state before data acquisition. The technique was developed on a MAGNETOM Sonata (Siemens, Erlangen, Germany). Other imaging parameters were: flip angle = 50^{o}–65^{o}, TR/TE = 4.3 ms/2.1 ms; NSA = 4; FOV/matrix size was adjusted to give a 1 mm^2 in-plane resolution; 2 mm slice thickness, and 40 mm slab thickness (~75% slice resolution, 20-40% over-sampling). Slabs were imaged with no gap and the imaging time was 3 – 4 min/slab. The technique was tested on 6 volunteers. For comparison, 2D multi-contrast TSE images with identical in-plane resolution were also acquired at one of the slab locations on 3 selected volunteers (ETL = 25, 240 Hz/pixel, NSA = 4, 4 mm thick, 10 slices with no gap, scan time ~ 4 min for T1W images and 8 min for T2W images). Standard multi-planar reconstruction (MPR) software was used for 3D visualization.

Results Fig 1 shows the 2D images of the aorta from one volunteer. Averaging effectively removes respiratory artifact. No blurring was noticed in trueFISP images. Fig 2 shows the MPR of the 3D data set from the same volunteer. The advantage of thin contiguous slices can be seen from the longitudinal depiction of the aortic walls (Figs 2b), even in a multi-slab acquisition (Fig 2c). The T1/T2 weighting of trueFISP can be seen in the CSF/spinal cord contrast in Fig 3. Blood suppression was not entirely effective at two regions when slabs were positioned axially: aortic arch (due to in-plane flow) and a portion of descending aorta (due to inflow of un-inverted blood from the heart or ascending aorta). Blood can be nulled in the latter case by simply positioning the imaging slab in an oblique orientation to exclude ascending aorta or most of the heart.

Figures Fig.1: 16 consecutive slices of aortic vessel wall with 2 mm thick and 1 mm^2 in-plane resolution. Note the complete suppression of the blood signal in the lumen and the clear delineation of the inner and outer boundaries of the vessel wall. Fig.2: Multi-planar reconstruction (MPR) of a 120 mm segment of the aorta (60 slices) acquired in ~10 min. (a) Axial slice showing the orientation of images (b) and (c). (b) A cut through the aorta and the spine showing high contrast among various structures. (c) A coronal cut of the aorta showing continuity of the vessel wall between adjacent slabs. Fig.3: Contrast comparison between (a) trueFISP and (b) T2W TSE. Similar vessel wall images were obtained but the sampling efficiency of trueFISP is ?? times higher than TSE.



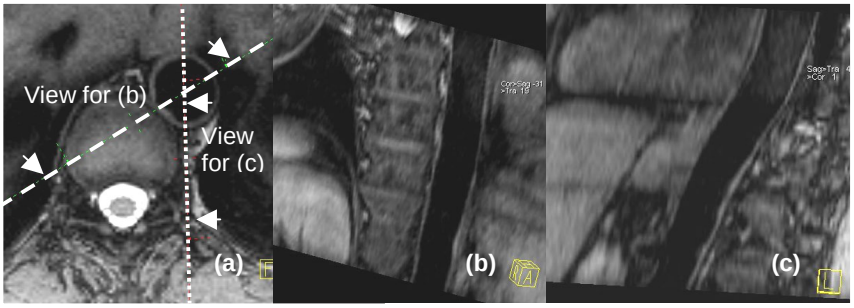
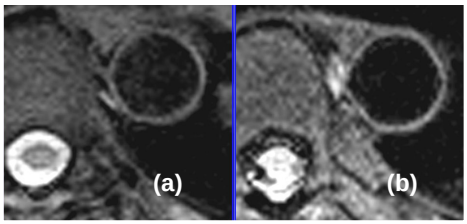


Figure 2 (top)

Figure 1 (left)

Figure 3 (right)



Conclusions The results demonstrated that 3D trueFISP allows aortic wall visualization not previously feasible in a reasonable scan time. Interleaving acquisitions in 2D based dark blood TSE improves scan efficiency [3] but not necessarily slice resolution. T2 weighted 3D TSE (e.g., [4]) requires a long scan time and use of long echo train introduces image blurring. 3D dark blood trueFISP not only reduces scan time but also gives T1/T2 contrast that complements existing multi-contrast TSE studies. Clinically, the 3D technique may allow for more efficient, high resolution evaluation of plaque load in the aorta, and opens new opportunities to the study of plaque morphology in 3D.

References [1] Fayad & Fuster, Neuroimaging Clin N. Am: 12(3), 2002. [2] Fayad et al., Cardiovascular MR, ed. Lardo et. Al. p.333-346, Mosby, 2003. [3] Parker et al., Magn Reson Med.;47(5):1017-21, 2002. [4] Lindsey et al., J Magn Reson Imaging: 17(5), 2003.