Rapid and Robust ToF-MRA with Mask Subtraction

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INTRODUCTION:

Conventional Time of Flight MRA relies on contrast between flowing blood and tissue. Part of the challenge in these techniques is saturating short T1 species (tissue and fat) while keeping the signal from blood (with a longer T1) unsaturated; thus this technique relies greatly on inflow. In the technique proposed here, the principle of contrast relies on subtraction of two data sets, one with signal from all spins and one collected with an arterial saturation band; subtraction of the two data sets yields an 'artery only' image.

The benefits of the proposed technique include (1) conspicuity of blood vessels which relies on the blood signal to noise ratio rather than on the blood-tissue contrast to noise ratio, and (2), the dependence of signal on blood saturation rather than tissue saturation, which in general allows one to see further down the vascular tree.

Subtraction of two data sets for imaging blood is not novel; examples of similar techniques are the digital subtraction of MR images before and after contrast injection, the use of subtraction in magnitude contrast ('rephase-dephase' MRA, and the use of arterial saturation bands for perfusion imaging.

Since the use of 'subtraction masks' in contrast MRA has become so popular, one may question why such methods have not been so prevalent in ToF methods. The answer probably lies in overall scan time, which would become prohibitively long if one were compelled to collect two data sets. One method to reduce scan times is reduction of resolution, which in general is not desirable.

METHOD:

To overcome this, the ToF method used here combines spiral imaging(1) for in-plane spatial encoding and half-Fourier encoding(2, 3) along the slice direction in a multi-slice experiment. Localized quadratic encoding(4) is added to increase the overall SNR. The resulting sequence:

- is very fast (1 axial slice, with a 196 diameter k-space matrix, is collected every heartbeat)
- retains adequate resolution (roughly 1.5 mm in all three directions)
- is very insensitive to turbulent flow-related phase (mitigating stenosis overestimation)

This method was implemented on a Siemens Vision 1.5 T scanner. Slices were spaced every 1.8mm (the half-Fourier method gives 1.5mm thick reconstructed slices), which means that coverage for two data sets (with, without arterial saturation) took roughly 1 heartbeat per mm for scan time.

RESULTS:

An example of this technique is shown in Fig. 1. The image in Fig. 1(a) shows an image from a single data set with a venous saturation band. Figure 1(b) shows a difference between two data sets, one with no saturation band and one with an arterial saturation band.

For both images, a coverage of 216 mm was obtained using a quadrature knee coil (FOV = 300 mm). The horizontal bands across the image in Fig. 1(b) are due to an inconsistent heart rate, which created uneven tissue signals in both data sets whenever the scan 'missed' an earlier R wave. The duration of the scan in Fig. 1(a) was 120 heartbeats; for Fig. 1(b) it was 240 heartbeats.

Fig. 1. 'Conventional' (a) and proposed difference method (b) MRA of popliteal bifurcation. The variant between the anterior and posterior tibial bifurcations is only clearly visualized in (b); additionally, some very small vessels are also seen in (b) which are not evident in (a).

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