High Resolution 3D MR Angiography using Arterial Spin Labeling

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Introduction

Arterial spin labeling (ASL) is a magnetic resonance perfusion imaging technique that uses the freely diffusible water in arterial blood as the tracer. In this technique, an inversion pulse is applied external to the imaging volume and blood is allowed to flow in, providing a signal that can be detected in the tissue as perfusion. The quantified cerebral blood flow can be used to study brain function and disease. This tagging out of the imaging volume has been used as a form of MR angiography (MRA). Most recently, E.T. Tan et. al. [1] applied a similar idea for blood vessel visualization, where parallel imaging was implemented. In this work, we present 3D high resolution MRA with increased signal to noise ratio (SNR) using in-plane slice-selective double inversion (IDOL) [2] prepared ASL.

Methods

A 3D Turbo-FLASH (TFL) sequence was modified to realize the 3D ASL technique, as shown in Figure 1. All the inversions were slab selective and centered on the imaging volume. In the tagging scan, a band with a thickness of 40cm was inverted, immediately followed by a second inversion band with the thickness of the imaging volume. After an inversion time (TI), 3D TFL imaging readout was performed to acquire all or part of the image k-space. Control scans with double inversions over the imaging volume were used to balance the potential magnetization transfer effect. The control signal subtracted from tagging signal will reflect the flow signal. To shorten the TFL readout, only a subset of the full 3D k-space was acquired with each inversion preparation. Two volunteers were imaged on a Siemens TIM Trio 3T MRI scanner using a 12 channel head coil following an IRB approved protocol. For one volunteer, 3D slabs of 8 low resolution slices (1.2 x 1.2 x 5 mm^3) were acquired with TI = [100, 200, 400, 600, 800, 1200, 1600, 2000, 2400, 3000] ms to determine the transit time of the arterial tagged spins. For the second volunteer, three high resolution 3D slabs were acquired with TR = 424 ms, TE = 3 ms, FA = 10 deg, voxel size = 0.4 x 0.4 x 0.6 mm^3, 80 slice locations, TI = [900, 1200, 1500] ms. For the high resolution acquisition, the phase encoding acquisition order was reversed such that all slice encodings were acquired in the TFL sequence after each inversion, and the phase encoding values were stepped for each inversion sequence.
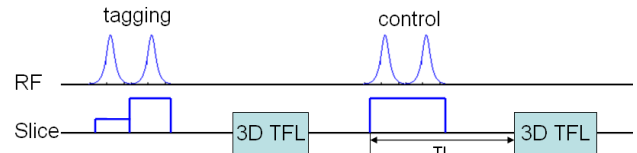

Figure 1. Schematic display of the pulse sequence including tagging and control scans. TI is the inversion time from tagging pulses to image readout.
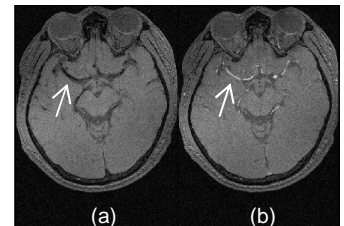

Figure 2. Anatomical (a) tagging and (b) control images. Signal from blood vessels differs greatly between the two scan as pointed by the arrows.

Results

Representative tagging(a) and control(b) anatomical images are shown in Figure 2. The difference between the control and tagged blood vessel signal is due to the different inversion magnetization preparation. In figure 3, the difference signals of control and tagging scans as a function of TI from three ROIs centered on different blood vessels are shown. For each vessel, the peak signal appears at approximately 800 ms indicating that the inflow time of arterial spins from tagging location to the imaging plane is 800 ms. Axial maximum intensity projection (MIP) images of the 3D high resolution MRA studies at TI of 900, 1200 and 1500 ms are shown in Figure 4. The strongest signal is seen for the case with TI = 900ms, and the signal decreases as TI increase. However, some small blood vessels that cannot be detected at TI = 900ms becomes visible at longer TI.
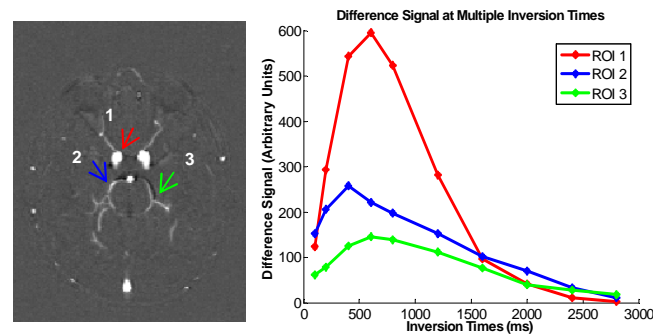

Figure 3. Difference of control and tagging signals at multiple TIs within three ROIs. ROI1 shows the highest signal overall and the peak signal appears at approximately 800 ms.

Conclusion

ASL was successfully implemented to perform 3D high resolution MRA. The technique has the advantage that the delay time can be adjusted to emphasize proximal or distal vessels.

References

[1] E.T. Tan, et. al, MR-Angioclub, Graz, 2008.
[2] G.H. Jahng, et. al, Med. Phys, 2007, 34(11), pp. 4519–4525.
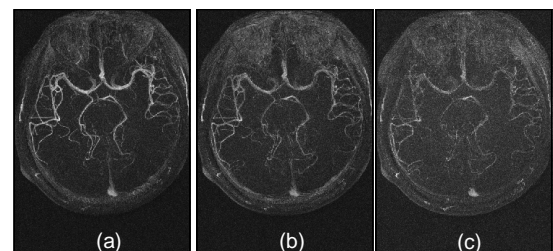
Acknowledgments

Figure 4. Axial MIP images of 3D MRA at TI of (a) 900ms, (b) 1200ms and (c) 1500 ms.