Dynamic MR angiography and microvascular flow imaging with high temporal resolution using TrueFISP based Spin Tagging with Alternating Radiofrequency (TrueSTAR)

L. Yan[1], Y. Zhuo[1], J. An[2], and J. Wang[3]

[1]Institute of Biophysics, Chinese Academy of Sciences, Beijing, China, People's Republic of, [2]Siemens Mindit Magnetic Resonance, Siemens Healthcare, MR Collaboration NE Asia, Shenzhen, China, People's Republic of, [3]Department of Radiology, University of Pennsylvania, Philadelphia, PA, United States

Introduction: Arterial spin labeling (ASL) methods have been increasingly applied for MR angiography (MRA) and perfusion imaging during recent years (1-4). The most appealing feature of ASL is that it does not require contrast agents that may induce nephropathy in a fraction of patients. However, compared to contrast-enhanced (CE) MRA and dynamic susceptibility contrast (DSC) perfusion MRI, the spatial and temporal resolution of existing ASL methods are still inferior. In this study, we developed a novel ASL technique termed TrueFISP based Spin Tagging with Alternating Radiofrequency (TrueSTAR) for both time-resolved 4-D dynamic MRA (dMRA) and microvascular flow (perfusion) imaging. TrueSTAR is a flexible technique that offers dynamic MRA with a spatial resolution of 1x1x1mm^3 and a temporal resolution of 50ms, as well as dynamic microvascular flow imaging with a standard spatial resolution of 3-4 mm and a temporal resolution <100ms.

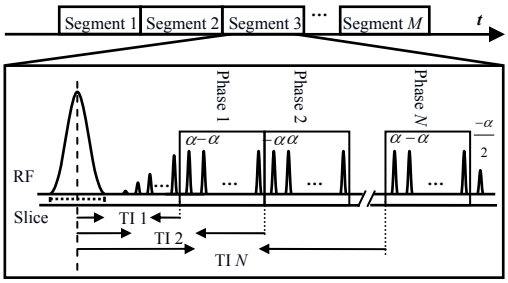

Fig1. The sequence diagram of TrueSTAR

Methods: Pulse sequence: The TrueSTAR technique combines ASL with a cine 3-D segmented multiphase TrueFISP sequence. As shown in Fig. 1, FAIR was used for spin tagging in this study. After selective or non-selective inversion pulses, 20 dummy RF pluses with ramp flip angles were applied to minimize transient oscillation. The signal was then continuously acquired by a segmented multi-phase TrueFISP readout.

Experiments: All experiments were performed on a Siemens Tim Trio 3T scanner (Erlangen, Germany) using 12-channel head coil. 4 subjects (age 24 ± 1 yrs, 3 male) participated in the TrueSTAR dynamic MRA experiment with the following parameters: FOV=220×165 mm^2, Matrix=224×162, 3D acquisition with 64 × 1mm slices, resolution =1×1×1mm^3, flip angle=30°, TR=3ms, TE=TR/2, rate-2 GRAPPA. The scans were ECG-triggered, and 10 to 15 phases with a step of 52 ms were acquired depending on the cardiac cycle. The scan time was approximately 6min. 2 subjects (age 22.5 ± 0.7 yrs, 1 male) participated in the experiment for dynamic microvascular flow imaging: FOV=220mm, Matrix=64×64, 3D acquisition with 4 × 5mm slices, resolution =3.4×3.4×5mm^3, flip angle=40°, TR=2.32ms, TE=TR/2. Twenty-nine phases between the TI of 97ms to 2817ms with a step of 85ms were acquired, and the scan time was 54s. For function MRI studies, the above scan was repeated 8 times while visual stimulation using flashing checkerboard was carried out during even scans (1, 3, 5&7 resting; 2, 4, 6&8 activation). In both dynamic MRA and microvascular flow experiments, a segmented Look-Locker (LL) EPI based FAIR sequence with closely matched imaging parameters was performed for comparison.

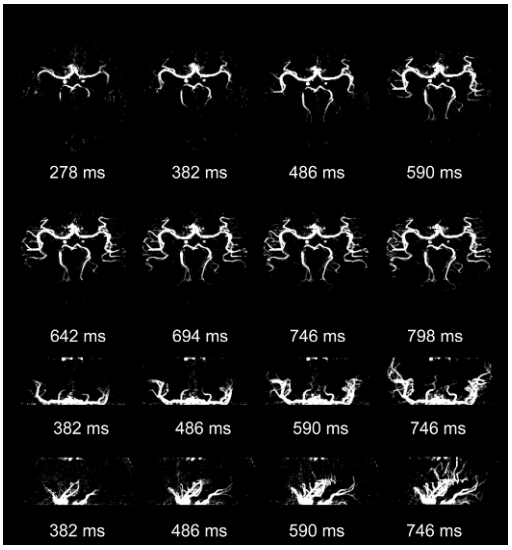

Fig2. MIP dMRA images acquired at representative phases form one subject using TrueFISP with a 52ms temporal resolution and 1×1×1mm^3 spatial resolution

Results: Fig2 shows the axial, coronal and sagittal views of the maximum intensity projection (MIP) dMRA images acquired at representative phases of one subject using TrueSTAR with ECG gating. One can appreciate the anatomical details of the dynamic filling of blood through the Circle of Willis into the main and small distal branches. Fig3 shows the series of TrueSTAR dynamic microvascular flow images from two slices of a representative subject. One can appreciate the dynamic transition from intravascular labeled blood in earlier phases to arteriolar and microvascular flow (perfusion) in later phases. The mean time courses during both resting and visual stimulation were extracted from the visual ROI and are shown in Fig4. The dynamic curves with 85ms resolution allowed accurate fitting of blood flow which was 78 and 149ml/100g/min during resting and activation respectively. However, both transit time and peak latency were prolonged by 100ms during activation which may be attributed to diluted arterial blood volume. Consistent with the visual appearance of high image quality, the signal-to-noise ratio and contrast-to-noise ratio of TrueSTAR were 29% and 39% higher than those of LL-EPI (p=0.028).

Discussion: TrueSTAR builds on the superior capability of TrueFISP for imaging blood signals (e.g. high T2/T1 ratio) which can be performed in the cine fashion to continuously measure the dynamic inflow (and washout) of labeled blood. TrueSTAR may be useful in the evaluation of hemodynamics in cerebrovascular disorders as well as for fMRI with improved temporal resolution.

References: [1] Wang J, *MRM* 2003; 49:796-802. [2] van Osch MJ, Med Image Anal 2006; 10: 59-70. [3] Edelman RR, *MRM* 1994; 31:233-238. [4] Yan L, *ISMRM* 2009, #2222.

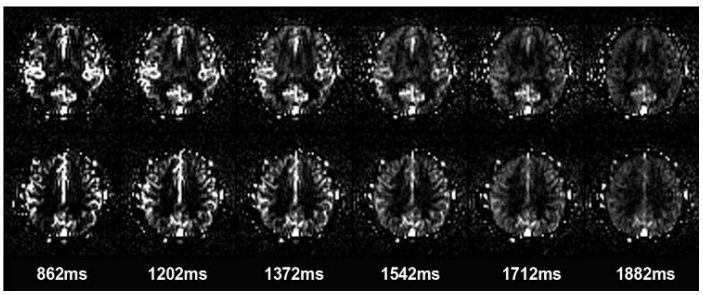

Fig3. Dynamic microvascular flow (perfusion) at representative phases from two slices of a subject

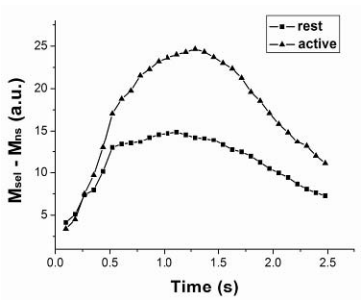

Fig4. The averaged curves of dynamic microvascular flow in visual ROI