Non-contrast Enhanced Time-Resolved 4D MRA using Multi-bolus TrueSTAR

Lirong Yan[1], and Danny JJ Wang[1]

[1]*Neurology, UCLA, Los Angeles, CA, United States*

Introduction:

Recently, a non-contrast enhanced time-resolved 4D MR angiography (MRA) technique termed TrueSTAR [1] has been developed by combining pulsed ASL with a segmented multi-phase balanced SSFP readout. Compared to contrast-enhanced MRA, this technique utilizes magnetically labeled arterial blood water as an endogenous contrast agent, and a temporal resolution of 50~100 milliseconds can be achieved. However, the SNR of this dynamic MRA (dMRA) technique is limited by the relatively small signal from labeled blood. Another limitation is the relatively short half life of the labeled blood (blood T1 of 1-2sec). As a result, one can only appreciate the dMRA signal within 1-2 seconds following the labeling pulse, causing difficulty for visualizing draining veins in arteriovenous malformation (AVM) patients [2]. Pseudo-continuous ASL is an alternative approach for dynamic MRA [2] which provides a longer bolus of labeled blood. However, the arterial inflowing phases have to be at least partially sacrificed due to the use of a long labeling RF pulse train. In this study, we developed a novel multi-bolus TrueSTAR technique to enhance and/or prolong the labeling bolus for 4D dMRA, without sacrificing imaging speed, temporal phases or resolution.

Pulse Sequence:

The multi-bolus TrueSTAR technique utilizes a train of intermittent HS inversion pulses for spin labeling. It takes advantage of the phenomenon that the magnetization of balanced SSFP can be temporally stored along z-axis by applying an $\alpha/2$ pulse, while magnetization preparation (e.g. spin labeling) can be performed. The steady-state precession can then be resumed by applying another $\alpha/2$ pulse [3]. Figure 1 shows the pulse sequence diagram of multi-bolus TrueSTAR. Spin tagging is implemented using the STAR scheme. Each inversion pulse (except the first one) is sandwiched by 2 $\alpha/2$ pulses and interleaved by a number of phases of balanced SSFP acquisitions. A pre-saturation pulse is applied at the beginning of the sequence.

Methods:

All experiments were performed on a Siemens TIM Trio 3T scanner. DMRA data was acquired by the multi-bolus TrueSTAR sequence. Three and four-bolus TrueSTAR sequences were implemented with the inversion pulses (except the first pulse) inserted after the phase number of 4/8, and 4/8/12, respectively. Imaging parameters were: FOV=220×165mm^2, resolution = 1×1mm^2, iPAT=2, a 3D slab of 40 slices with 1.5mm thickness was scanned to cover the Circle of Willis. The thickness of the inversion slab was 80mm, with a gap of 20mm between the inversion and imaging slabs. 22 phases from 150 to 2370ms with a step of 105ms were acquired within a total scan time of 7min. For comparison, a single-bolus TrueSTAR sequence was performed with the same imaging parameters. DMRA images were generated by subtraction between label and control acquisitions, and maximum intensity projection (MIP) images were generated for each phase along three directions (transverse, sagittal, coronal).

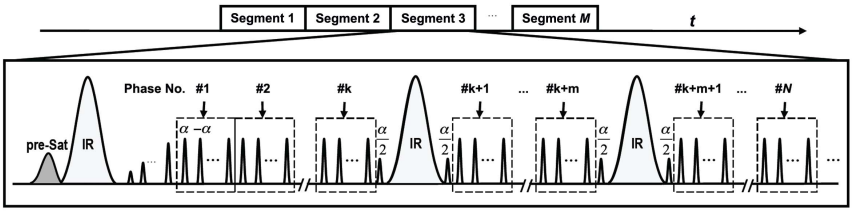

Figure 1. Pulse sequence diagram of multi-bolus TrueSTAR

Results and Discussion:

Figure 2 shows axial MIP images of dMRA acquired using single-bolus (first row), three-bolus (second row) and four-bolus (last row) TrueSTAR. Compared to the single-bolus images, a prolonged/enhanced bolus of labeled blood and consequently an increased duration of the bolus passage were achieved by multi-bolus TrueSTAR. The peak SNR of single, three and four-bolus TrueSTAR dMRA within the main arteries of ACA, MCA and PCA was 27.2, 28.9 and 29.2, respectively. The area-under-the-curve of single, three and four-bolus TrueSTAR dMRA was 380, 706 and 893, respectively. The dynamic course of labeled blood flowing through the Circle of Willis into the main and fine distal branches can be visualized with both high spatial and temporal resolution using multi-bolus TrueSTAR. This technique is highly flexible and can produce a sharp bolus with high intensity or a prolonged bolus with steady signal, depending on the specific application in individual subjects. A prolonged/enhanced labeling bolus of dMRA should benefit the depiction of draining veins in AVMs, without penalty in scan time or temporal resolution.

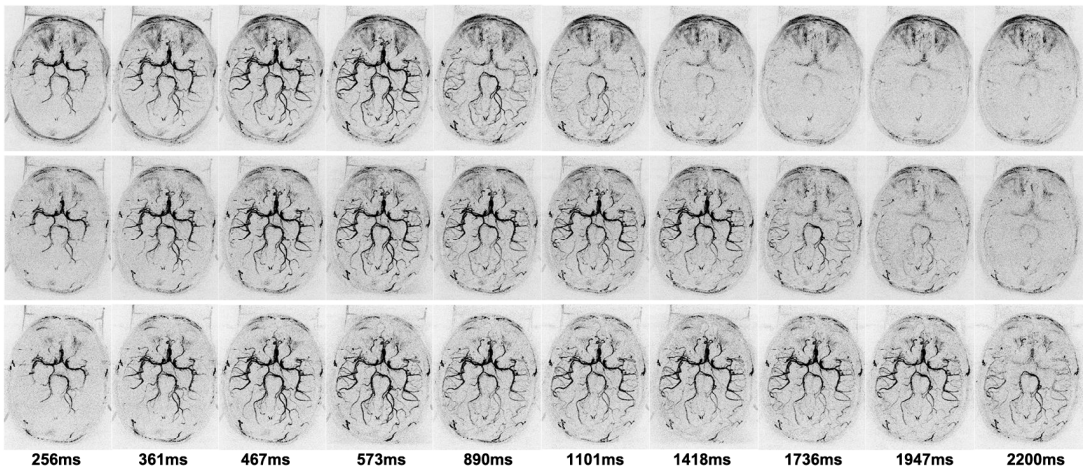

Figure 2 Axial MIP images of dMRA at 10 representative phases acquired with single-bolus (first row), three-bolus (second row) and four-bolus (last row) TrueSTAR from one subject. A prolonged label bolus is clearly visible with multi-bolus TrueSTAR.

References:

[1] Yan, L. et al., Radiology 256:270-9, 2010. [2] Xu, J. et al., JMRI 34:1199-205, 2011. [3] Robson, PM et al., Radiology 257(2):507-15, 2010. [4] Scheffleer, K. et al., MRM 45:1075-80, 2001.