Optimization and Application of Simultaneous Triple Contrast, T1, Arterial TOF and BOLD Venography at 7T

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Introduction

The success of 7T MRI will ultimately depend on demonstrating its effectiveness for clinical applications, which in turn requires a wide range of contrast options. Specifically T1 contrast is important in combination with T1 Gd chelate contrast agents to depict abnormal vasculature, disruption of the blood brain barrier or inflammation. While simple spin echo and gradient echo images exhibit only limited T1 contrast, inversion recovery prepared turbo field echo (IR-TFE) sequences have produced favorable results. The goal of this study was to assess and optimize contrast with IR-TSE with dual gradient echoes for simultaneous acquisition of T1-weighted images, time-of-flight arteriograms, and BOLD venograms.

Methods

Ten healthy subjects (26-52y) were imaged with the dual IR-TFE sequence on a 7T MRI system (Philips, Achieva, Cleveland) using a transmit/receive head coil (TR/flip angle=13ms/8°, TE =2.2 and 11ms, TI=1350ms, shot interval=2800ms, FOV=230x184mm^2, matrix= 384x267, 100 slices, slice thickness=1.6 mm, interpolated voxel size 0.45x0.45x0.8mm, scan time=6 min). In some subjects, multi-slab 3D-TOF MRA and/or 2D-T2* fast field echo susceptibility weighted images were collected for comparison. In other subjects additional studies were done to evaluate SNR and CNR behavior as a function of TI, TR and shot interval. Five subject were also scanned at 3T with similar parameters, but TE=20ms for the second echo to account for the longer T2* and resultant TR=23ms.

Results

Excellent T1 contrast is obtained in the short echo images, and arteries appear bright due to inflow enhancement, whereas veins appear dark on the second echo due to paramagnetic deoxyhemoglobin (Fig. 1). Since T2* are shorter at 7T compared to 3T, shorter TE and thus shorter TR can be used for susceptibility weighted imaging, thus making 7T MRI more time efficient for BOLD venography, in addition to having approximately 2-fold better SNR. In comparison with dedicated multi-slab TOF-arteriograms, the vessel CNR is somewhat decreased because signal from brain parenchyma is higher on short echo IR-TFE. Likewise, 2D BOLD venograms show more venous detail than second echo IR-TSE, because SNR is higher in the surrounding brain. Images at different TI with a fixed shot interval show a wide range of contrast (Fig. 2). Note that CSF does not follow the expected pattern, but is dark on short TI images. This may be due to motion and/or because the signal calculation (dashed line Fig. 2.) did not include effects of the finite shot interval which was shorter than CSF T1. Overall SNR increased with increasing TR of the TFE shots, thus the second echo data may be acquired at no extra time.

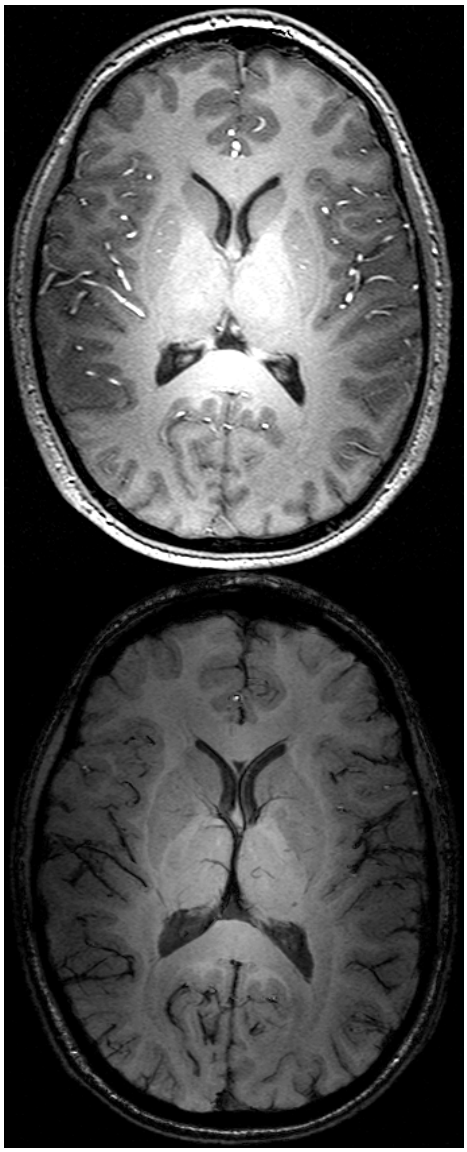

Fig.1. (Top) First echo T1-weighted, TOF arteriogram (single slice). (Bottom) Second echo BOLD venogram (minimum intensity projection of 5 slices).

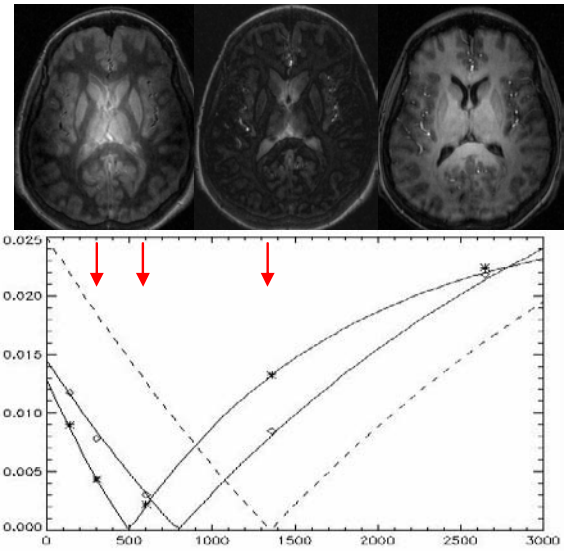

Fig.2. IR-TFE images with TI=300, 600, 1360 ms (shot interval 2800ms) and fitted signal intensity for gray matter (*), white matter (○) , and computed signal for CSF (dashed line).

Discussion

The triple contrast features achieved at 7T with the dual echo IR prepared TFE sequence may be ideally suited for generation of fast high resolution overviews for assessment of neurological disorders. In the future, the performance of this triple contrast sequence may be further improved by numerical simulations e.g. optimization of the flip angle variation during the TFE read out shot [1,2]. Furthermore, shorter T1 with Gd chelates, should improved depiction of arteries on the first echo time-of-flight images in addition to depicting enhancing lesions, and shorter T2* may decrease venous signal on the second echo images thus improving contrast.

References

[1] Epstein FH, et al, MRM 31, 164-177 (1994)
[2] Deichmann R et al, NeuroImage 12, 112-127 (2000)