Optimized Post-Processing of 7Tesla Simultaneous Triple Contrast: T1-weighted, TOF Arteriography, and BOLD Venography

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<u>Introduction</u>
TOF-MRA data are typically acquired with gradient echo sequences such that parenchymal tissue signal is much lower than vascular signal thus allowing simple MIP processing to generate angiographic views, producing excellent arterial depictions at 7T [1]. Similarly, 7T can produce outstanding depiction of venous vasculature based on the BOLD effect [2]. It was previously shown that IR-prepared dual turbo gradient echo sequences (IR-dTFE) can simultaneously generate exquisite T1 contrast, bright arteries on the first echo and dark veins on the second echo, where arterial depiction is comparable or better than with standard TOF-MRA. However, because of the high signal for brain and skull, simple MIP processing is no longer possible. We present here a method to overcome this problem, by combined processing of the first and second echo images.

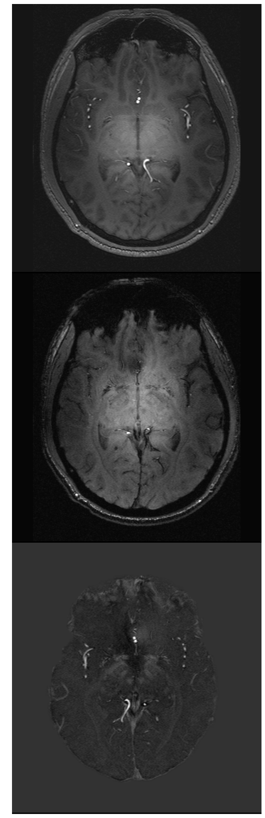

Fig 2: First echo (TOF), second echo (BOLD), and processed difference image.

<u>Method</u>
Ten subjects (age 26-52y) were imaged at 7T (Philips, Achieva, Cleveland) with the IR-dTFE sequence (TI/shot interval= 1300/2700ms TR/TE1/TE2/flip angle = 13/2.5/10.5ms/8^o, and voxel sizes ranging from 0.43x0.53x1.2 to 0.57x0.81x1.6mm3). Comparison TOF-MRA data with identical resolution were acquired in 5 of these subjects. Data were pre-processed off-line using IDL (ITT Corporation). First, skull signal was removed through a sequence of three dimensional erosion, region growing, and dilation steps. Erosion of thresholded data separates brain and skull signals, after which a region growing operation captures the separated brain tissue. A dilation operation compensates for the erosion step, resulting in a mask that covers the entire brain. Second, a weighted difference between the first and second echoes was calculated in which vessels are enhanced while signal from surrounding tissues is minimized. In a few cases, we also explored Laplacian of Gaussian (LoG) filtering to further enhance depiction of vascularity, in particular small vessels. Pre-processed echo data were imported into TeraRecon (TeraRecon, Inc., Japan), a three dimensional viewing environment, and evaluated by trained radiologists.

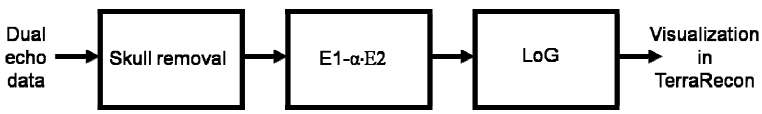

Fig. 1: Block diagram illustrating processing steps.

<u>Results</u>
Figure 2 shows example first and second echo images, as well as the resultant subtracted image. In the pre-processed images, some artifacts were observed near air tissue interfaces, due to greater intra-voxel dephasing and distortion in the second echo image. In addition, skull signal removal was not completely successful in the most superior section due to the curvature of the head, near the eyes and sometime in inferior sections where high field RF inhomogeneity lead to signal reduction preventing full removal of non-bran signal. Adjusting the weighting factor for the subtraction allowed variability in the amount of suppression of surrounding tissues. Increasing the factor from a ratio of mean intensities of first and second echo datasets to slightly higher values allowed for increased suppression of veins at the cost of suppressing brain tissue. Data preprocessing times were about 4-5 minutes, and limited by loading and writing of data.
The contrast in the subtracted images (about 60) was high enough to allow for simple MIP processing and 3D viewing on TeraRecon (Fig 3). Second and higher order branches of the circle of Willis could be depicted. Adding LoG filtering could remove parenchymal tissue signal, but caused some distortion in vascular structures. In addition, radiologists perceived the presence of residual brain signal as useful for orientation.

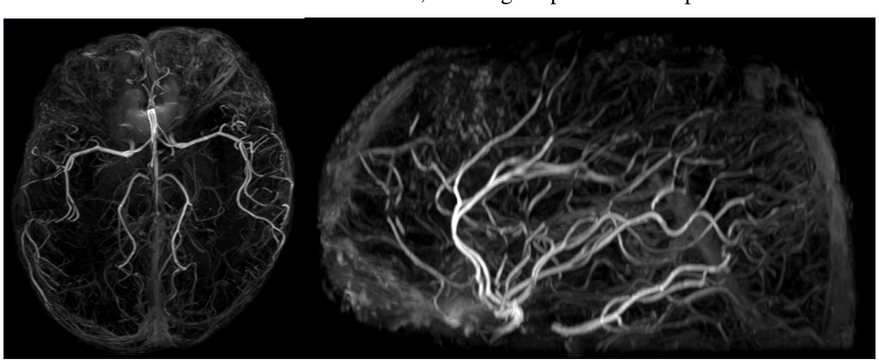

Fig 3: Axial and sagittal MIPs. Arteries including the anterior, middle, and posterior arteries, and their first and second order branches are most intense. Veins including the superior sagittal sinus, straight sinus, inferior sagittal sinus, and vein of Galen, as well as small branches are seen with intermediate signal. Brain parenchyma is almost completely suppressed. Some residual signal is seen near the eyes.

<u>Conclusion</u>
Our study shows that with optimized pre-processing MIP arteriograms can be generated from IR-prepared dual turbo gradient echo sequences. Thus the IR-dTFE sequence may be fully utilized at 7T for simultaneous acquisition of high quality T1-weighted images, as well as for depiction of arteries and veins. This will minimally provide time savings, but may also provide new previously unavailable information.

<u>References</u>
[1] Heverhagen JT et al, ISMRM 06
[2] Abduljalil et al, JMRI 18, 284-290, 2003
[3] Schmalbrock P et al, ISMRM 07