# Effects of High Field on Magnetization Prepared Angiography

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**Introduction** Imaging at high fields presents several unique challenges, among them increased inhomogeneity of the transmission field and the longer $T_1$ relaxation times. Herein, we present high field 4.7T images created with magnetization prepared magnetic resonance angiography[1] (MP-MRA). The technique uses inversion recovery (IR) to create gated in-flow angiograms with background tissue suppressed. The IR 3D gradient echo pulse sequence facilitates imaging at high fields within clinical time and SAR constraints, while accounting for vessel pulsatility and $B_1$ inhomogeneity. The longer $T_1$ values of brain tissue at high fields can be exploited to provide improved blood-to-background contrast by easing the time requirements of background nulling, and thus increasing allowed time for blood in-flow.

**Methods** The carotid arteries and intracranial circulation of normal volunteers was imaged on a 4.7T system (Varian INOVA) with a triggered IR gradient echo pulse sequence (MP-MRA). The pulse sequence timing was as follows: TR=9.7ms, TE=3.6ms, and for an example heart rate of 60 bpm, inversion time (TI) = 333 ms, and an intersegment delay of 347 ms, with several dummy segments preceding the start of acquisition. A matrix size of 384 (readout; zero filled to 512) × 256 × 32 was used, for a total scan time of about 4min30s per slab, and an effective voxel volume of .429 mm × .859 mm × 1 mm. Two overlapping 32 mm slabs from the same volunteer were combined into a single MIP image, and acquisition was gated to the subject's heart beat via the pulse detected by a finger sensor. A standard adiabatic pulse was used for in-plane inversion. A second inversion slab offset from the imaging slab was used to reduce signal from veins. Each 3D partition was divided into segments comprising 32 centrically ordered phase views, with an excitation flip angle of 20°. A volunteer was also imaged with a 2D version of the MP-MRA sequence with varying TI (Fig. 2). Numerical simulations were performed to determine the optimal sequence parameters required to attain complete background suppression and maximal inflow time for the IR angiograms (Fig. 3). A volume coil was used for transmission and reception.

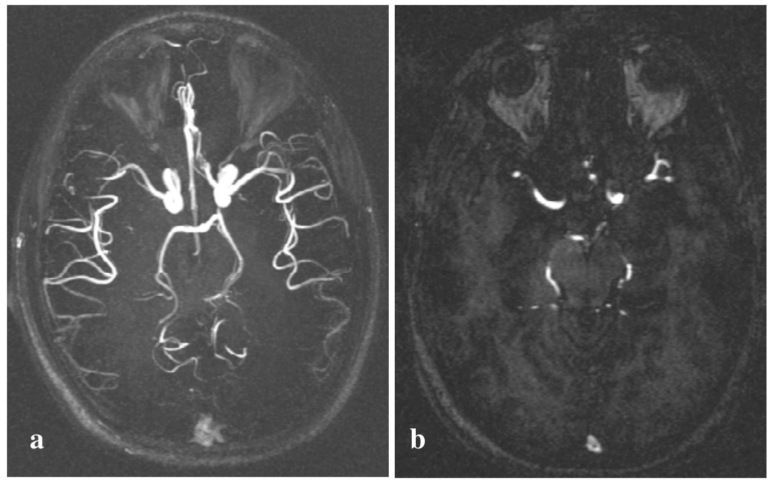


**Fig. 1** a) High field (4.7 T) complete 50 slice 3D gated MP-MRA MIP image with 50mm coverage of vascular territory. No image processing was performed other than simple filtering. b) A 1mm thick source image.

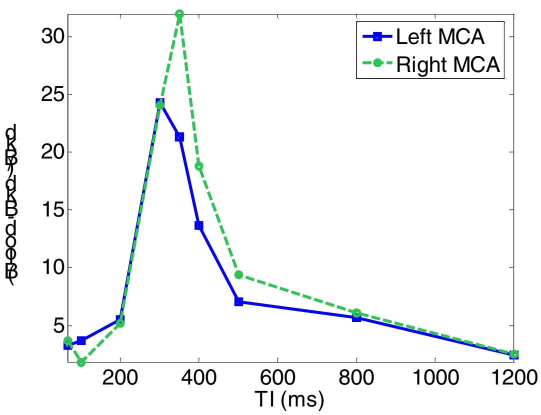


**Fig. 2** 4.7 T blood contrast measured with gated 2D MP-MRA in a volunteer's middle cerebral arteries as a function of inversion time (TI). The range of maximum blood contrast occurs when TI is close to optimal for background suppression, approximately 350 ms in this case.

**Results** MIP in-flow angiograms of the circle-of-Willis were acquired as shown in Fig. 1a, consisting of many 1 mm thick slices from the imaging volume as in Fig. 1b. The images show good background tissue suppression and good blood to background contrast. Of note is the fact that the smaller distal arteries at the sides of the head are clearly visible, even with the reduced flip angles in this region due to high field $B_1$ inhomogeneity[2]. It is also important to notice the fact that the background tissue has been suppressed with a high degree of uniformity. In addition, blood contrast in the middle cerebral arteries as a function of inversion time was measured by experiment (Fig. 2), and shown to be optimal only within a tight range of TI's.

**Discussion** At 4.7T, through the use of IR with appropriate TI times, one can improve the blood-to-background contrast of in-flow angiograms. From Fig. 2 it is evident that only a certain range of TI's allow for good blood-to-background contrast at high field strength with this technique. The increased $T_1$ relaxation times at 4.7T can be exploited by permitting more time for in-flow after inversion compared with lower fields (Fig. 3), while still providing the appropriate timing to suppress background signal. Furthermore, the use of IR can produce images with flatter RF profiles across the brain, mitigating the high field RF standing wave effect. The increased SNR available at 4.7T further increases the achievable CNR. Smaller, distal intracranial arteries at the sides of the head are visible at high field using a single transmit and receive volume coil. In conclusion, high field MP-MRA vascular lumen imaging is a feasible technique, clearly displaying fine vessel detail.

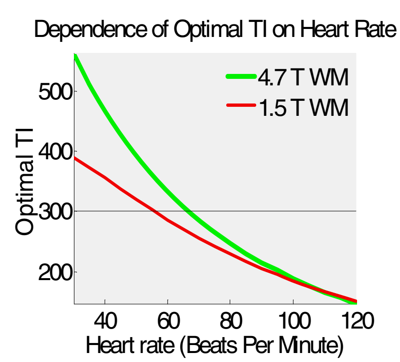


**Fig. 3** Effect of field strength on the inversion time (TI) required to null white matter (WM). TI is greatly increased at high field for lower heart rates. This extra inflow time increases blood signal.

**References** [1] Li *et al.*, MRM 31:414-422 (1994). [2] Thomas *et al.*, MRM 53:1452–1458 (2005)