High-resolution Black-blood MRI of Carotid Atherosclerotic Plaque at 3T: Optimization of Clinical Protocol

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Introduction:

Since introduction of 3T scanners into clinical practice, advantages of high-field MRI have been extensively explored in many radiological applications. In the imaging of carotid atherosclerotic plaque, no systematic studies were conducted in order to evaluate benefits and limitations of 3T and suggest optimal protocols.

Purpose:

To optimize a protocol for black-blood carotid MRI at 3T and compare the performance of carotid imaging on 1.5T and 3T scanners.

Methods:

Experiments were conducted on 1.5 and 3T scanners (GE Medical Systems) using four-element phased-array coils with the identical geometry. The multicontrast protocol included T_1-, T_2- and proton density (PD)-weighted 2D black-blood fast spin-echo sequences with following parameters TR(ms)/TE(ms)/echo train: 800/10/10 for T_1-, 2500/50/12 for T_2-, and 2500/9/12 for PD-weighted scans. For black-blood imaging with long TR (PD- and T_2-weighted), a multislice double inversion-recovery (DIR) method (1) was used with 4 slices per TR. Inversion times (TI) were 272 ms for 1.5T and 281 ms for 3T, which correspond to blood T_1=1200 ms at 1.5 and 1550 ms at 3T (2). T_1-weighted images were obtained using single-slice DIR with TI=335 and 349 ms for 1.5T and 3T respectively. For each contrast weighting, different combinations of the matrix size (MTX=256,384,512) and the number of excitations (NEX=1,2) were tested. All images were obtained with FOV=14-16 cm and slice thickness of 2 mm. Comparison of 1.5T and 3T performance was outlined from the identical examinations of six healthy volunteers. Optimized clinical 3T protocol (see below) was tested in four patients with advanced carotid atherosclerosis.

Results:

The multislice DIR method provided time-efficient black-blood imaging without exceeding SAR limits at 3T. Flow suppression was identical at 1.5 and 3T for both single- and multislice DIR. An average factor for SNR increase at 3T vs.1.5T was about 1.6±0.3. Observed SNR gain at 3T was less than the theoretically expected value (2.2 times) based on field increase and impedance of our coils. We address this issue to increased tissue saturation at 3T due to longer T_1's. SNR improvement at 3T was sufficient to use NEX=1 and the same or higher resolution. Fig.1 illustrates the fact that SNR at 3T obtained with twice-increased resolution and NEX=1 is comparable to a standard 1.5T protocol (MTX=256, NEX=2). SNR limitations at 3T were more restrictive for T_2-weighted imaging, where an acceptable image quality could not be achieved with MTX=512 and NEX=1. Taking into account the need of identical resolution for all contrast weightings, we recommend a fast 3T protocol for routine applications with NEX=1 and in-plane resolution ~0.4 mm, i.e. MTX=384 and FOV=16cm (Fig.2).

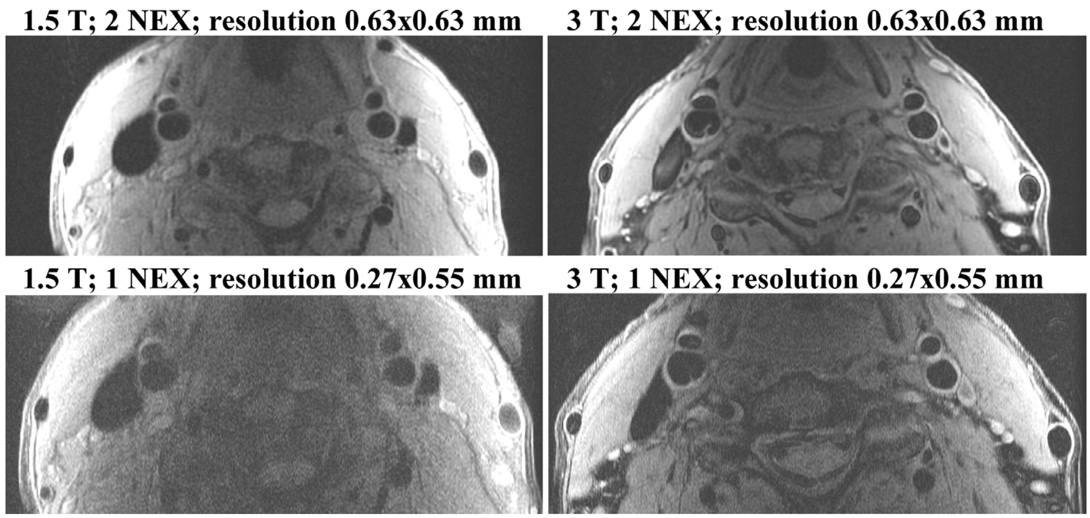

Fig. 1. Comparison of high-resolution T_1-weighted black-blood images of carotid arteries obtained from a healthy volunteer at 1.5 and 3T with different in-plane resolution and NEX. Top row: FOV/MTX = 16cm/256; bottom row: FOV/MTX = 14cm/512.

Conclusions:

Black-blood imaging of carotid arteries at 3T benefits from considerable increase of SNR. We developed a state-of-the-art protocol based on 3T advantages in combination with the time-efficient multislice DIR technique. Optimal use of a 3T scanner for carotid MRI provides either a 50%-reduction of scan time or simultaneous increase of resolution and reduction of scan time with a factor of 1.5, as compared to 1.5T imaging.

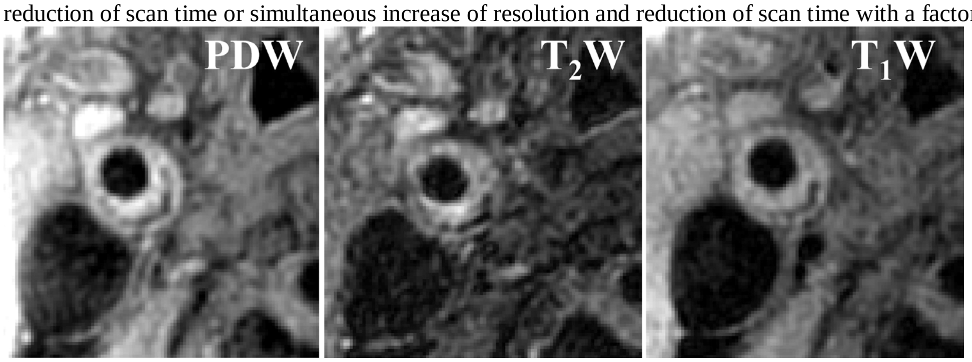

Fig 2. Multicontrast images of atherosclerotic plaque obtained at 3T with NEX=1 and in-plane resolution of 0.42 mm. Scan time was 1 min per four slices for T_2-weighted and PD-weighted scans, and 25 s per slice for a T_1-weighted scan. Images show semicircular area of calcification (dark) and variable signal intensity within the plaque.

References:

1. Yarnykh VL, Yuan C. JMRI 2003;17:478-483.
2. Noeske R, et al. MRM 2000;44:978-982.