MR Neurography using Robust Fat and Blood Suppressed Volumetric T2-Weighted Imaging

Xinzeng Wang[1], Crystal E Harrison[1], Yogesh K Mariappan[2], Karthik Gopalakrishnan[2], Avneesh Chhabra[1,3], Robert E Lenkinski[1,3], and Ananth J Madhuranthakam[1,3]
[1]Radiology, UT Southwestern Medical Center, Dallas, Texas, United States, [2]Philips Innovation Campus, Philips Healthcare, Bangalore, Karnataka, India, [3]Advanced Imaging Research Center, UT Southwestern Medical Center, Dallas, Texas, United States

Introduction: Magnetic Resonance Neurography (MRN) enables direct multiplanar visualization of the nerves and is helpful in the evaluation of multiple peripheral nerve pathologies.[1,2] To improve the conspicuity of the nerves, 3D MRN sequences typically utilize short tau inversion recovery (STIR) technique for fat suppression, often at the expense of signal to noise ratio (SNR). In recent years, chemical-shift acquisitions (i.e. Dixon approaches) have been developed to achieve uniform fat suppression without the SNR penalty, but these techniques typically require longer scan times due to the acquisition of multiple echoes in separate repetitions.[3] An additional concern that commonly exists with MRN is the presence of blood vessels in the close proximity of the nerves that often confound the visualization of these nerves. Recently, motion sensitized driven equilibrium (MSDE) has been proposed for blood suppression,[4] however, the hard radiofrequency (RF) pulses of MSDE are prone to artifacts from B_0 and B_1 inhomogeneities that are commonly encountered in difficult areas, such as the brachial plexus resulting in reduced SNR.

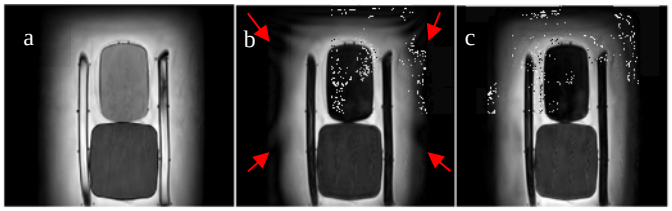

Fig. 1. Flow phantom images acquired with standard TSE (a), water-only images with dual echo TSE-mDixon and standard MSDE (b) and BIR-4 based MSDE (c). Note the increased B_0 and B_1 inhomogeneity artifacts with standard MSDE (arrows in b) compared to BIR-4 based MSDE (c). V_{enc} of 1 cm/sec suppressed flow with both MSDE acquisitions (b and c).

The purpose of this work was to implement an adiabatic pulse (BIR-4) based MSDE[5] to reduce its sensitivity to B_0 and B_1 inhomogeneities in combination with a dual-echo 2-point Dixon technique to acquire both echoes in the same repetition of a 3D turbo spin echo (TSE) technique for volumetric neurography in clinically feasible scan times.

Methods: Bloch equation simulations were performed to optimize the BIR-4 parameters within the constraints of the peak B_1 of the 3 T body coil (13.5 uT), and the optimized BIR-4 was implemented as a preparation module in a TSE sequence. The TSE sequence was later modified to acquire both in-phase (IP) and out-of-phase (OP) echoes within the same repetition (TSE-mDixon). Partial echoes were used to maintain the IP and OP interval (1.2 ms at 3T), and homodyne reconstruction with phase preservation was used to successfully reconstruct the fat and water separated images.

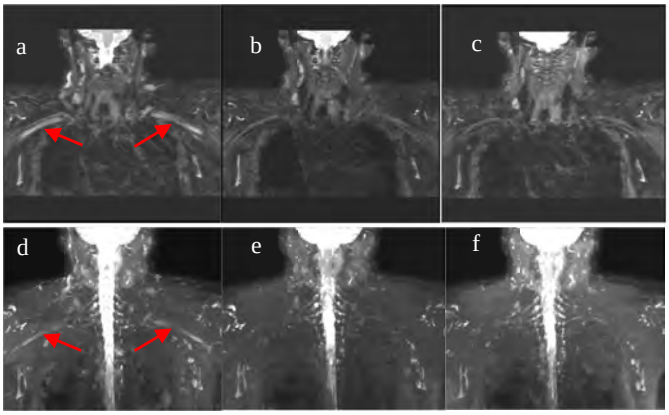

Fig. 2. T_2-weighted water-only images from TSE-mDixon without blood suppression (a), with standard MSDE (b) and with BIR-4 based MSDE (c) and their corresponding MIPs (d-f). The blood vessel signal (arrows) was suppressed with a V_{enc} of 3 cm/s on images acquired with MSDE (b,c,e,f).

All experiments were performed on a 3 T Ingenia scanner (Philips Healthcare, The Netherlands). The BIR4-based TSE-mDixon sequence was first validated and compared against standard MSDE in a flow phantom. Subsequently, MRN was performed on the brachial plexus of 3 normal volunteers with IRB approval and written informed consent. T_2-weighted images were acquired with both 2D and 3D TSE-mDixon acquisitions. The gradients were empirically set to induce a velocity encoding of 3 cm/s, such that the signal from the arteries and veins were sufficiently suppressed. Other scan parameters include: coronal orientation; 1) 2D: TR/TE = 6056/30ms; resolution = 1×1×4 mm^3; 2) 3D: TR/TE = 1800/155ms; resolution = 1×1×1mm^3.

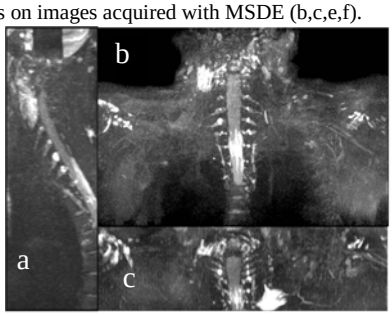

Fig. 3. MIPs in sagittal (a), coronal (b) and axial (c) orientations from a 3D acquisition.

Results: The total duration of the BIR-4 pulse was set to 24 ms with a 4 ms delay to reduce the sensitivity to B_0 and B_1 inhomogeneities within the peak B_1 of the body coil. Both standard MSDE and BIR-4 achieved flow suppression in the flow phantom (fig. 1), but the sensitivity to B_0 and B_1 inhomogeneities is more pronounced with standard MSDE (fig. 1b) as compared to BIR-4 (fig. 1c). The acquisition of both echoes in the same repetition reduced the scan time by approximately 40% compared to an acquisition, where the IP and OP echoes were acquired in separate repetitions (e.g. 1:30 min vs. 2:40 min). In human volunteers, both the standard MSDE and BIR-4 achieved good blood suppression (arrows in figs. 2a, 2d), but the SNR of the image with BIR-4 (fig. 2c, 11.1) was approximately 2 times better compared to the image with standard MSDE (fig. 2b, 5.8) and equivalent to the standard TSE without blood suppression (fig. 2a, 11.0). The maximum intensity projections (MIPs) show increased conspicuity of the nerves with superior SNR in the images acquired with BIR-4 (fig. 2f). Volumetric acquisition in the coronal plane (fig. 3) shows exquisite details of the nerves in orthogonal orientations with uniform fat and blood suppression acquired in approximately 6 minutes 38 seconds.

Conclusion: BIR-4 based MSDE with chemical-shift acquisition provides robust blood and fat suppression even in the presence of B_0 and B_1 inhomogeneities (e.g. brachial plexus) with superior SNR and improves the conspicuity of the nerves. The acquisition of both echoes required for Dixon processing in the same repetition provides isotropic resolution in volumetric acquisitions in clinically feasible scan times.

Reference: 1) Stoll G et. al., J Neurol 256 (2009); 2) Filler et. al. J NeuroSurg 85 (1996); 3) Reeder SB et. al., JMRI 24 (2006). 4) Shankaranarayanan A et. al. ISMRM, 19 (2011); 5) Mugler JP et. al. ISMRM 17 (2009).