MR Nerve Imaging using Blood Suppressed 3D T2 Weighted Imaging with Uniform Fat Suppression

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Introduction: Magnetic Resonance nerve imaging (1) is the direct imaging of nerves, in which the resonance signal arises from the nerve itself rather than from surrounding tissues or from fat in the nerve lining. MR nerve imaging has been shown to be useful in evaluation of major nerve compressions such as those affecting the sciatic nerve (e.g. piriformis syndrome), the brachial plexus nerves (e.g. thoracic outlet syndrome), the pudendal nerve, or virtually any named nerve in the body.

Fat-suppressed T_2-weighted methods (2), DW EPI (3) or DW SSFP (4) have been commonly shown to detect the nerves. Conventional fat suppression can suffer from non-uniform saturation in the presence of B_0 and/or B_1 inhomogeneities, when used with T_2-weighted methods. It is also difficult to delineate nerves from vessels because of their similar signal intensity in T_2-weighted and SSFP images. Moreover, current DW methods suffer from artifacts due to, image distortions (when used with EPI acquisitions) and can be very sensitive to magnetic field inhomogeneities.

To image the tortuous nerves, it would be desirable to acquire volumetric T_2-weighted images with uniform fat suppression and minimized signal from the surrounding blood vessels. In this work, we have developed such an imaging sequence by integrating a modified 2-point chemical-shift technique (5) with 3D FSE based acquisition (6), to achieve uniform fat suppression and motion-sensitizing driven equilibrium (MSDE) preparation (7,8) to suppress blood vessel signal. Results have been obtained from various parts of the body to reconstruct high-resolution 3D MR nerve images.

Methods: An investigational version of 3D-FSE, using variable refocusing flip angles and extended echo trains (6), was used in this study. The sequence was altered to acquire two echoes (in-phase and out-of-phase respectively) in two sequential repetitions. The two echoes were then processed with a modified 2-point Dixon method (5) to reconstruct separate fat and water images. This reconstruction uses an efficient and robust phase-correction algorithm and has been shown to produce images with uniform fat and water separation even in the presence of B_0 inhomogeneities (9). Blood suppression was achieved with an MSDE preparation module (7) using 90_x, 180_y, 90_{-x} RF pulses and motion sensitizing gradients, inserted in front of the modified 3D-FSE acquisition.

MR nerve imaging was performed on normal volunteers with IRB approval and informed consent. Images were acquired on Signa HDxt 1.5T and a 3T scanners (GE Healthcare) using Neuro-Vascular (MedRad Inc) array coil. 8-channel cardiac coil was used for abdomen and pelvis scans. Scans were performed to image nerves originating from C-spine, T-spine and L-spine levels. Respiratory gating was used for performing nerve imaging in the T-spine. The motion sensitizing gradients were empirically set to induce a velocity encoding of 4.9 cm/sec, such that the signal from the vessels near the nerves were sufficiently suppressed. The duration between 90_x and 90_{-x} was approximately 8.2 ms. The acquisition parameters were: Coronal orientation, FOV = 300×300 mm^2, $N_x \times N_y$ = 256x256, slice thickness = 1.6 mm, no. of slices = 64, TE_{eff} ~ 104ms, ETL = 60, TR = 3000ms (~3900ms with respiratory gating), scan time = 6:28min (increased to ~8min with resp gating) with an auto-calibrated parallel imaging (10) factor of 2 along the phase encoding and slice encoding direction. The modified Dixon technique allowed 4 different sets of images to be obtained from single acquisition (in phase, out of phase, fat and water). All these images were qualitatively evaluated for usefulness in detection of nerves.

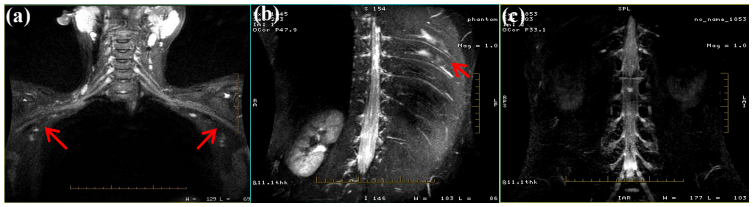

Figure 1: Maximum intensity projection images for visualizing the nerves in different regions. (a) brachial plexus (b) abdomen and (c) pelvis. Note the extent of the nerves seen even in difficult regions like brachial plexus and abdomen. These images were obtained from a 1.5T scanner.

Results: Initial results have shown that the water-only images provided the maximum information for nerve imaging, while the remaining contrast images provided additional information regarding the surroundings of the nerves. Targeted MIPs from the brachial plexus, abdomen and the pelvic regions acquired on a 1.5T system are shown in Figure 1a, 1b and 1c respectively. Note that even in difficult regions like the brachial plexus (Figure 1a), fat suppression was found to be uniform thus allowing visualization of great lengths of the brachial plexus nerves. Figure 2 shows the images acquired on a 3T scanner from the brachial plexus region (shown with inverse contrast). Figure 2a shows the unsuppressed image, while 2b shows the fat suppressed image. Higher SNR can be seen in these images. Also note the better visualization of nerves in Figure 2b due to the uniform fat suppression. Figure 3 shows zoomed in image of brachial plexus nerves (3b) and its comparison to anatomical drawings (3a). The details in the MR nerve images have been shown to match with that of drawings

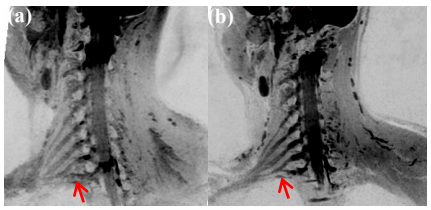

Figure 2: Maximum intensity projection images (from 3T scanner) for visualizing the nerves in brachial plexus region. (a) Unsuppressed image and (b) fat-suppressed image. Note that unsuppressed image (a) do not give the details of the nerves but provide complementary information in terms of the surrounding tissue.

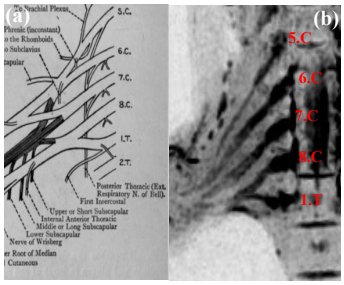

Figure 3: Zoomed image of the brachial plexus nerves (b). (a) Shows the corresponding drawing from an anatomical textbook. Note that the details in (b) matches with the drawings.

Discussion: This technique provides both fat-suppressed (water-only) and non-fat-suppressed images from the same acquisition, which allows for perfect co-registration, while simultaneously providing high-resolution MR nerve images. In addition, this technique also generates unsuppressed images that could be used for additional information. Enhancements to acquire both in-phase & out-of-phase images in the same repetition could further decrease the total acquisition time or increase the spatial resolution.

Reference: **1)** Howe et al, MRM 28(2): 328–38 (1992); **2)** Filler et al, J NeuroSurg 85(2):299-309 (1996); **3)** Takahara, et al. Radiology, 249(2):653-60 (2008) **4)** Zhang et al, AJNR (2008) **5)** Ma. MRM 52: 415-419 (2004); **6)** Busse et. al. MRM 60: 640-649 (2008); **7)** Wang et. al. MRM 58: 973-981 (2007); **8)** Balu et. al. MRM 64:(2010); **9)** Ma et. al. JMRI 31: 889-894 (2010); **10)** Beatty ISMRM 07; p. 1749.