T2-weighted Volumetric Acquisition with Water-Fat Separation in a Clinically Feasible Scan Time

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Introduction: Most clinical applications require the acquisition of volumetric T1 and T2-weighted images with and without fat suppression. Isotropic high resolution imaging of 3D volumes is desirable because the acquired images can be reformatted to any desired orientation. While high spatial resolution 3D T1-weighted images can be acquired in clinically feasible scan times (due to their short TR), high resolution 3D T2-weighted images have historically required prohibitively long scan times (1). Hence, routine clinical T2-weighted imaging still depends largely on 2D multi-slice acquisition in multiple planes (sagittal, axial, and/or coronal) in order to achieve high resolution in all three dimensions, considerably lengthening examination time. A new method, 3D FSE eXtended Echo Train Acquisition (XETA) was recently introduced that uses very long echo trains and variable refocusing flip angles to allow acquisition of high spatial resolution 3D T2-weighted images with clinically useful contrast and feasible scan times of 5 to 10 minutes (2).

A second problem that increases total scan time is the frequent need to acquire one or more planes with and without fat suppression. IDEAL (Iterative-Decomposition of water and fat with Echo Asymmetry and Least-squares estimation) (3, 4) is a chemical-shift based method that generates robust water-only, fat-only, in-phase (fat+water), and out-of-phase (water-fat) images from a single three-point acquisition. IDEAL has been shown to provide better fat suppression in T2-weighted 2D images than conventional fat-suppression techniques (5). In this work, we demonstrate the acquisition of volumetric T2-weighted water and fat separated images in a single sub ten-minute acquisition by integrating the IDEAL method with the very long echo train 3D FSE XETA technique.

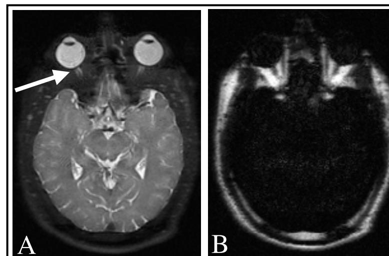

Fig. 1. Water (A) and fat (B) images in the brain.

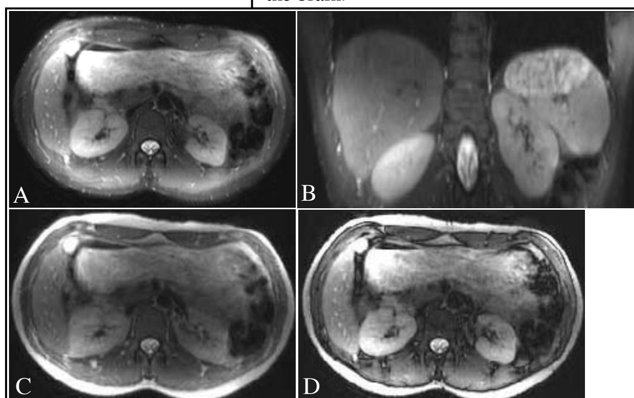

Fig. 2. Water only axial (A), coronal reformat (B), in-phase axial (C) and out-of-phase axial (D) images of the abdomen acquired using respiratory gating in 7 minutes.

Materials and Methods: The IDEAL technique requires acquisition of three images with relative fat-water phase shifts of $-\pi/6$, $\pi/2$, and $7\pi/6$ (3), increasing the total scan time by a factor of three relative to a standard sequence. Furthermore, the spacing of the refocusing pulses in each echo train must be increased in order to accommodate the shifted echo times, thus lengthening the echo train and potentially increasing blurring of tissues with short T2 relative to the echo train length. To partially offset these issues, we used a 2D accelerated autocalibrating parallel imaging method (6) to reduce the number of acquired phase and slice encodes.

After IRB approval, volunteer data were acquired on a 1.5T TwinSpeed MR imaging system (GE Healthcare, Waukesha, WI). Typical imaging parameters included: TR = 2500 ms, TE = 60-100 ms, BW = $\pm$ 31.25 kHz, matrix = $256 \times 256 \times 40$, partial Fourier sampling along the phase encoding direction. FOV varied between 14 cm (for ankle) to 36 cm (for pelvis) based on the anatomy and acceleration factors between 1.5-3 were applied. The standard 3-point IDEAL processing algorithm (with homodyne reconstruction for partial sampling (7)) was used to reconstruct water-only, fat-only, in-phase (water+fat) and out-of-phase (water-fat) images. All images were acquired in less than ten minutes.

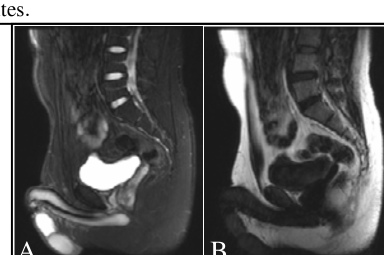

Fig. 3. Water (A), fat (B), images in a male pelvis.

Results: **Fig. 1** shows water and fat separated images in the head. Notice the conspicuity of the optic nerve (arrow) and uniform fat suppression around the orbits. **Fig. 2A** shows the water-only abdominal axial image acquired using respiratory gating and **fig. 2B** shows the coronal reformat from the 3D acquisition showing high resolution in the slice direction. Using the water-only and fat-only images, in-phase (**fig. 2C**) and out-of-phase (**fig. 2D**) images can also be generated. **Figs. 3A-B** show similar water and fat separated images in a male pelvis, while **figs. 4A-B** show ankle images. Note the uniform fat suppression in all of the water-only images.

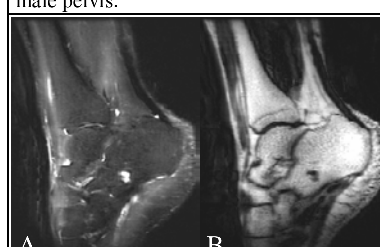

Fig. 4. Water (A), fat (B), images in an ankle.

Discussion: We have demonstrated acquisition of high-resolution T2-weighted 3D images of both water and fat in a single scan. These images can be reformatted into any desired plane and can be combined to provide images with and without fat suppression as well as in-phase and out-of-phase contrast, potentially allowing several 2D acquisitions to be replaced with a single 3D acquisition of reasonable length. Although application of IDEAL increases the echo spacing, parallel imaging can compensate by reducing the echo train length. Likewise, the three-point IDEAL technique increases the number of overall samples required, but with a 3-fold increase in SNR, higher parallel imaging factors can be applied. This new sequence has the potential to provide rapid acquisition of a wide variety of diagnostically useful information.

Reference: 1) Imhof H, Eur. Radiology 2002, 12: 2781-2793. 2) Busse RF, MRM 2006, 55: 1030-1037. 3) Reeder SB, MRM 2004, 51: 35-45. 4) Reeder SB, MRM 2005, 54: 636-644. 5) Reeder SB, JMRI 2006, 24: 825-832. 6) Brau ACS, ISMRM 2006, 14: 2462. 7) Reeder SB, MRM 2005, 54: 586-593.