High spatial resolution, volume selective 3D FSE imaging

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Introduction: Although conventional multi slice 2D FSE is routinely used for tissue characterization of both malignant and benign processes, diagnostic limitations become apparent in small (e.g. prostate) and complex, tortuous (e.g. perianal fistulae) structures. It would be advantageous to use a high spatial resolution 3D acquisition scheme with thin sections that would permit multiplanar reformatting. Until recently, the appeal of a near-isotropic 3D FSE acquisition has been beset by blurring caused by long echo-train lengths needed to maintain reasonable scan times. Modulation of the refocusing flip angles in FSE to minimize signal modulation from T_2 relaxation has enabled the use of long echo trains [1-3]. In this study, we developed a novel technique that combines inner-volume (IV) selection [4] and highly selective spatial saturation bands [5] with an eXtended Echo Train Acquisition (XETA) 3D FSE-Cube sequence. This pulse sequence, called IV-XETA, was evaluated for imaging of the prostate and perianal fistulae.

Methods: Pulse sequence design- A 3D-XETA-Cube pulse sequence was modified to incorporate inner volume selection. XETA employs modulated refocusing flip angles [1,2] for long echo-train lengths, an auto-calibrating hybrid space parallel imaging scheme with acceleration along phase and section encoding dimensions [3] and an optimized view ordering scheme for a non-separable k_y-k_z grid [6]. Inner volume selection was achieved by applying the slice selective gradient for the excitation pulse along the phase encoding direction. To improve the selectivity profile further and eliminate any residual aliasing, highly selective saturation RF pulses with narrow transition bands [5] were applied at the edges of the excitation and refocusing slabs. Scan time and TR were unaffected by these additions, as they were played during the otherwise quiescent period between echo trains of the non-SAR limited sequence.

Experiments- All images of the pelvis were acquired on a Signa EXCITE HDx 3T system (General Electric Healthcare, Waukesha, WI) and an eight-channel torso coil (GE Coils, Cleveland, OH). Typical scan parameters for IV-XETA were as follows- 320x224 matrix, 80-100 slices 1.2-1.6 mm thick, 20-24 cm FOV, TE/TR 100ms/2s, ETL 70-80, BW ±83 kHz, acceleration factors 1.8-3X, scan time 3.5-4.5 min. Conventional 2D FSE images were acquired on all 3 orthogonal imaging planes for comparison (320x224 matrix, 24-32 slices 3 mm thick, 2-3 NEX, 20-24 cm FOV, TE/TR 100ms/2s, ETL 12, BW ±83 kHz, scan time 3-4 min.). Typically, chemical fat suppression was used when imaging fistulae for both the 2D and 3D scans for better visualization. Data were acquired on 12 subjects (5 healthy subjects, 7 patients with perianal fistulae) after prior informed consent per guidelines of the institutional review board. The 2D FSE and the 3D IV-XETA images were compared for SNR, artifacts and spatial resolution.

Results: Figure 1 shows a comparison of XETA with no volume selection or sat bands (A) with sat bands alone (B), with inner volume selection alone (C) and with inner volume ***and*** sat bands (D). Notice that the combination of the two selection schemes (D) has eliminated all aliasing artifacts along section and phase encoding dimensions despite the small FOV. Figure 2 compares coronal (A) and axial (B) slices from a 2D FSE prostate exam to corresponding sections from a 3D coronal slab (C) and an axial reformat (D), acquired using the proposed IV-XETA sequence. The 2D scans were 4 min. long compared to the 5 min. IV-XETA 3D scan. Note minimal artifacts in the reformatted section due to the high spatial resolution of the coronal volume. Figure 3 shows a coronal section (A) and a reformatted axial (B) section acquired using the IV-XETA sequence with fat suppression on a patient with perianal fistula, which was depicted very clearly in both the imaging planes. Two views of a volume rendered coronal slab are shown in Fig. 3C and 3D, demonstrating both the high resolution of the 3D dataset and the utility of the 3D acquisition, which facilitates Parks's classification of perianal fistula.

Conclusion: The use of a novel, high spatial resolution volume selective 3D FSE-Cube sequence was demonstrated for T_2 weighted imaging of small and complex structures such as the prostate and perianal fistulae. Using IV-XETA, a typical 3D slab with a 320x256x96 matrix with 1.4 mm thick sections was acquired in 5 minutes compared to three separate 2D scans with comparable matrix dimensions, 3 mm thick slices and a total scan time of ~ 12 minutes. Post processing of near-isotropic 3D acquisitions allowed optimal visualization of small, tortuous structures, obviating complex, often uncertain, scan plane prescriptions with 2D methods. True isotropic acquisition would require sub-mm section thickness and would necessitate the use of signal averaging to recover the concomitant SNR loss, at the cost of scan time increase. The addition of fat suppression to 3D IV-XETA improves outlining of simple and complex abnormal structures. IV-XETA can potentially replace conventional 2D FSE sequences in the sagittal and/or coronal planes, improving scan efficiency.

References: [1] Mugler et al. ISMRM 2000, p687. [2] Busse et al. MRM, 55:1030-7 (2006). [3] Busse et al. ISMRM 2007, p1702. [4] Feinberg et al. Radiology, 156:743-747 (1985). [5] Le Roux P. ISMRM 1997, p1538. [6] Beatty et al. ISMRM 2007, p1749.

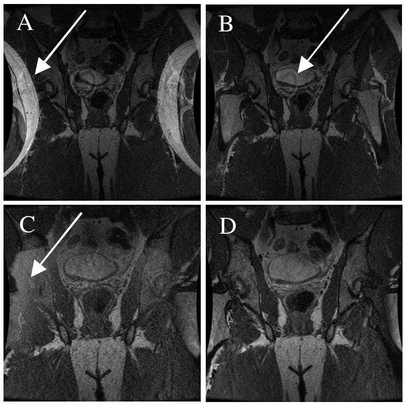

Figure 1. Comparison of a section from a 3D IV-XETA with no sat pulses or inner volume selection (A) with sat pulses alone (B), with inner volume selection (C) and with both sat pulses **and** inner volume selection (D). Note that all residual aliasing artifacts are eliminated in (D).

Figure 2. Coronal (A) and axial (B) 2D FSE images of the prostate compared to corresponding sections from a coronal 3D IV-XETA scan (C) and an axial reformat of the 3D slab (D).

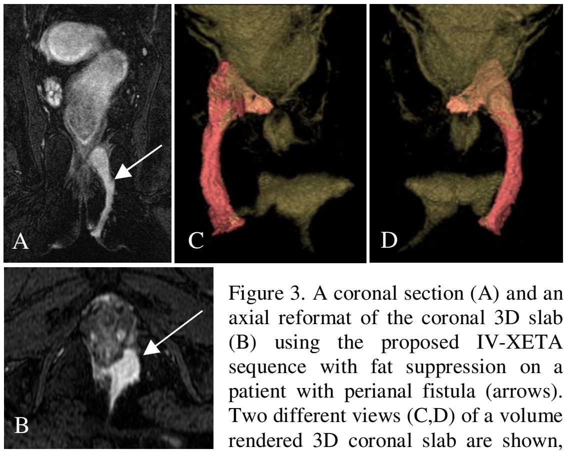

Figure 3. A coronal section (A) and an axial reformat of the coronal 3D slab (B) using the proposed IV-XETA sequence with fat suppression on a patient with perianal fistula (arrows). Two different views (C,D) of a volume rendered 3D coronal slab are shown, illustrating the benefit of using a near-isotropic 3D scan over conventional 2D scans.