Clinical evaluation of a novel, near-isotropic resolution volume selective 3D FSE pulse sequence for prostate MRI

D. W. Stanley[1], M. Saranathan[2], M. B. Wood[3], J. F. Glockner[3], and A. Kawashima[3]

[1]GE Healthcare, Rochester, MN, United States, [2]Global Applied Science Laboratory, GE Healthcare, Rochester, MN, United States, [3]Department of Radiology, Mayo Clinic, Rochester, MN, United States

Introduction: MRI is the preferred investigation for tumor localization and local staging prior to prostate carcinoma treatment despite its current limitations. Typically, multi-slice 2D Fast Spin Echo (FSE) sequences in three orthogonal planes aligned to optimally visualize the prostate are used to outline the contour and zone anatomy of the prostate gland and to reveal gross tumor extension to the seminal vesicles and neurovascular bundles. It would be advantageous to use a high-resolution 3D acquisition scheme with thin sections, permitting multiplanar reformation in arbitrary planes, especially for the visualization of the prostate gland contour and peri-prostatic tissue. Also, it could potentially reduce the overall examination time by replacing one or more of the 2D acquisitions with a single 3D acquisition. In this study, we investigated a novel, volume-selective near-isotropic 3D FSE-Cube pulse sequence and its potential as an adjunct and/or replacement to conventional multiplanar 2D FSE imaging.

Methods: Pulse sequence- An inner volume eXtended Echo Train Acquisition (IV-XETA) 3D FSE pulse sequence was developed. XETA employs modulated refocusing flip angles [1,2], an auto-calibrating hybrid space parallel imaging scheme [3] and an optimized view-ordering scheme for a non-separable k_y-k_z grid [4]. Inner volume selection [5] was achieved by playing 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 [6] were applied at the edges of the excitation and refocusing slabs. Scan time and TR were unaffected by the addition of saturation bands as they were played during the otherwise quiescent period between echo trains.

Experiments- All imaging was performed on a 3T Signa HDx MR scanner (GE Healthcare, Waukesha, WI) using an eight-channel phased array torso coil (GE Coils, Cleveland, OH). Eight subjects (seven with no known pathology, one with prostate cancer after external beam radiation) were imaged after prior informed consent. After the localizer scans, multi-slice 2D FSE were acquired in 3 orthogonal planes followed by a coronal 3D IV-XETA scan. The scan parameters for the 2D FSE sequence were as follows: TR/TE 4000 ms/105 ms, ±50 kHz bandwidth, 3 mm slice thickness, slice gap 0.2 mm, 384x256 matrix, echo train length 16, 3 NEX, 22 cm FOV, 20-24 slices, scan time ~ 4 min. Scan parameters for IV-XETA was as follows: TR/TE 2200 ms/108 ms, ±62 kHz bandwidth, 1.2 mm slice thickness, number of slices-100, 320x256 matrix, echo train length 70, 1 NEX, 22 cm FOV, scan time ~ 5 min. The 3D IV-XETA coronal volume was reformatted to match the same location, slice thickness and FOV as the 2D FSE scans. Images were retrospectively evaluated by two abdominal radiologists in consensus for depiction of prostate contour and peri-prostatic structures, perceived SNR, sharpness and degree of image artifact, grading on a 5-point scale. The sequences were also ranked in order of preference. A non-parametric signed test was used to assess statistical significance.

Results: Compared to coronal 2D FSE, both source and coronal reformatted images of 3D IV-XETA were equally useful in outlining the prostate contour and seminal vesicles. With regard to perceived SNR and overall image quality, reformatted 3D IV-XETA images were superior to corresponding 2D FSE images ($p < 0.05$) for all imaging planes. However, direct axial 2D FSE images were superior to reformatted axial 3D IV-XETA in the depiction of the neurovascular bundles and seminal vesicles due to inferior in-plane resolution of the reformats ($p < 0.05$). Coronal 3D IV-XETA was preferred to coronal 2D FSE in four of the six cases. Figure 1 compared 2D FSE images obtained in coronal, sagittal and axial plane with corresponding reformatted sections obtained using IV-XETA on a normal subject. The original coronal section (C) is also shown to illustrate the high spatial resolution of the 3D acquisition. Figure 2 showed the comparison on a patient with known prostate tumour for coronal and axial planes.

Conclusions: Our preliminary results suggest that 3D IV-XETA sequence with multiplanar 2D reformation is promising for prostate imaging and has the potential to replace direct coronal and/or sagittal 2D FSE sequences at 3.0 T. Further study in patients with prostate cancer remains necessary to determine the accuracy for local staging with 3D IV-XETA. With a 32-channel system, it might be possible to achieve an SNR that could permit true isotropic sub-mm^3 voxel 3D acquisition, which could potentially eliminate the need for conventional 2D FSE imaging.

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

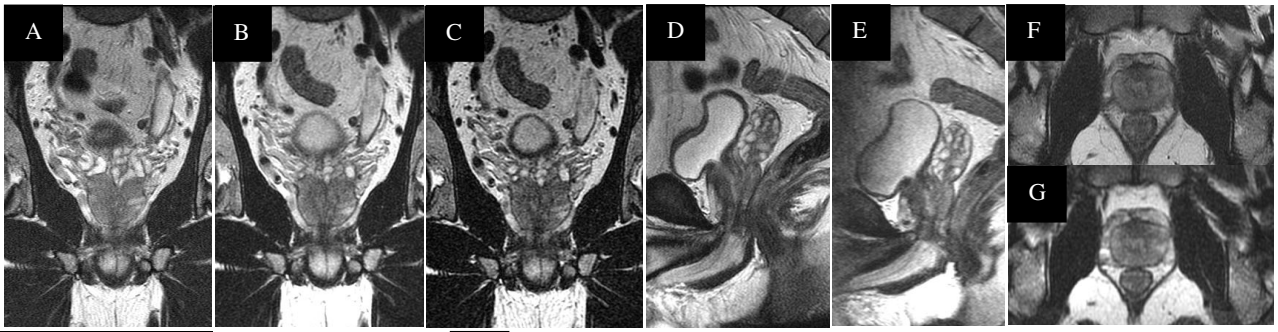

Fig 1. Coronal 2D FSE (A), source (B) and reformatted (C) 3D IV-XETA images of the prostate. Sagittal/axial 2D FSE images (D,F) with corresponding reformatted sections from 3D IVXETA (E,G)

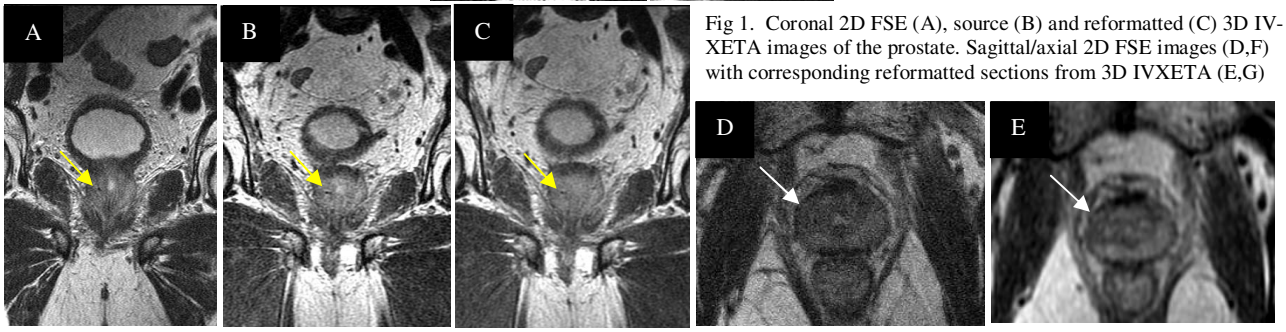

Fig. 2. Coronal 2D FSE (A), source (B) and reformatted (C) 3D IV-XETA images in a patient who after external beam radiation for prostate cancer (arrows- gold seed marker). Recurrent tumor is better defined on axial reformatted 3D IV-XETA (E) than 2D FSE (D)(white arrows).