High spatio-temporal resolution dynamic contrast enhanced MRI of the prostate

A. Kawashima[1], M. Saranathan[2], S. Gupta[3], and D. Rettmann[2]

[1]Radiology, Mayo Clinic, Rochester, MN, United States, [2]Global Applied Science Lab, GE Healthcare, Rochester, MN, United States, [3]Global Research Center, GE Healthcare, Niskayuna, NY, United States

Introduction: Dynamic contrast enhanced MR imaging (DCEMRI) of the prostate has been shown to improve the detection, localization and tumor staging of prostate carcinoma and to supplement the limitations of morphologic T_2-weighted imaging including significant improvement of specificity [1]. Fat suppressed 3D SPGR sequences have been utilized for DCEMRI of the prostate with the usual trade-off between spatial and temporal resolution. There has been a renewed interest in pharmacokinetic modeling of tumors, specifically in generating quantitative parametric maps (K^{trans} and k_{ep}), due to their role in assessment of response to medical therapy. However, the generation of reliable parametric maps requires a high spatio-temporal resolution acquisition methodology, usually achieved at the cost of spatial resolution or coverage. In this study, we investigated the use of a highly accelerated fat saturated elliptic centric 3D TRICKS [2] acquisition for dynamic high spatial and temporal resolution DCEMRI of the prostate and its potential utility in pharmacokinetic modeling on a 3T system.

Methods: Pulse sequence- A variable rate fat suppression scheme compatible with elliptic centric *k*-space ordering and its use in combination with TRICKS for hepatic DCEMRI was reported in [3]. Following each fat selective IR pulse, a variable number of elliptical centrically ordered *k*-space lines are acquired, the exact number being dependent on the distance from the origin of *k*-space. In order to minimize the modulation in *k*-space and the attendant ringing artifacts even further, a variable fat saturation flip angle scheme was incorporated to minimize signal modulation across *k*-space. Bloch equation simulations were employed to compute the flip angle modulation for the fat inversion pulse. For the TRICKS *k*-space segmentation, elliptical centric k_y-k_z space was divided into four equal annular regions (A-D) and a post contrast acquisition schedule of ABACADABAC… was employed following the acquisition of an ABCD pre-contrast scan. Linear interpolation was used to generate full k-space for each acquired annular region, yielding four times higher effective temporal resolution compared to conventional 3D SPGR acquisitions.

Experiments- Seven patients including five patients with proved prostate cancer prior to radical prostatectomy and two patients with minimally elevated PSA values, 0.8 and 1.2 ng/mL, respectively, following radical prostatectomy, were evaluated after prior informed consent on a GE EchoSpeed 3T Excite system (GE Healthcare, WI, USA) using an endorectal-eight channel phased array (PA) coil configuration in six patients and with an eight-channel PA coil in one patient. Following a localizer scout scan, T_2-weighted FSE images were acquired in all three orthogonal planes. For DCEMRI, an elliptical centric fat suppressed 3D SPGR sequence with a TRICKS *k*-space scheduling as described above was used in an oblique axial plane. A SENSE-based parallel imaging scheme (R=2) reduced the scan time by a factor of 2. The sequence parameters were as follows: 15° flip; +/-62.5 kHz bandwidth; TR/TE=3.9ms/1.8ms; 56-64 reconstructed slices of 2.4-3mm slice thickness; 20-26 cm FOV; 320x224/256x192matrix; 0.5 NEX. The smaller FOV and higher matrix were used with the endorectal coil, which afforded higher SNR and small FOVs. Effective temporal resolution was 2.5-3.5s. Typically, the number of reconstructed phases varied from 17-25 with most of the phases covering the first 1.5 min. The acquisition of the final 5 phases was staggered to image the contrast washout phase. Pharmacokinetic modeling was performed using custom developed software (Cinetool, GE Healthcare) written using IDL (ITTVIS, Boulder CO). A two compartment General Kinetic Model was fit to the data using an empirical vascular input function [4]. Parametric maps (K^{trans} and k_{ep}) were generated from the high temporal resolution data and compared to those generated using conventional SPGR imaging data wherever an earlier examination was available and using every fourth phase from the 3D TRICKS reconstruction if a prior 3D SPGR examination was not available.

Results: Prostate carcinoma was better depicted on high spatio-temporal resolution DCEMRI source images than T_2 FSE images in all five patients. The lesions appeared more conspicuous and better correlated with the enhancement zone in the 3D post contrast images on the K^{trans} maps obtained from high temporal resolution sequence (Figs. 1H, 2B) compared to the low temporal resolution maps (Figs. 1G, 2A). The T_2 FSE, DCEMRI, and K^{trans} map data were negative for recurrent tumor in both patients with PSA failure after radical prostatectomy.

Conclusion: The combination of an endorectal coil and/or multichannel PA coil and 3T afforded increased SNR which permitted us to accelerate both using parallel imaging and using the shared *k*-space TRICKS scheme. Initial results of the proposed DCEMRI sequence are promising. We are currently correlating the parametric maps with clinical outcomes and assessing the positive predictive values of the technique.

References:

[1] Ocak et al. AJR, 189: 192-201 (2007). [2] Korosec et al. MRM. 36:345-51 (1996). [3]. Saranathan et al. ISMRM 2006, p2207 [4]. Galbraith et al. NMR Biomed. 15: 132-142 (2002).

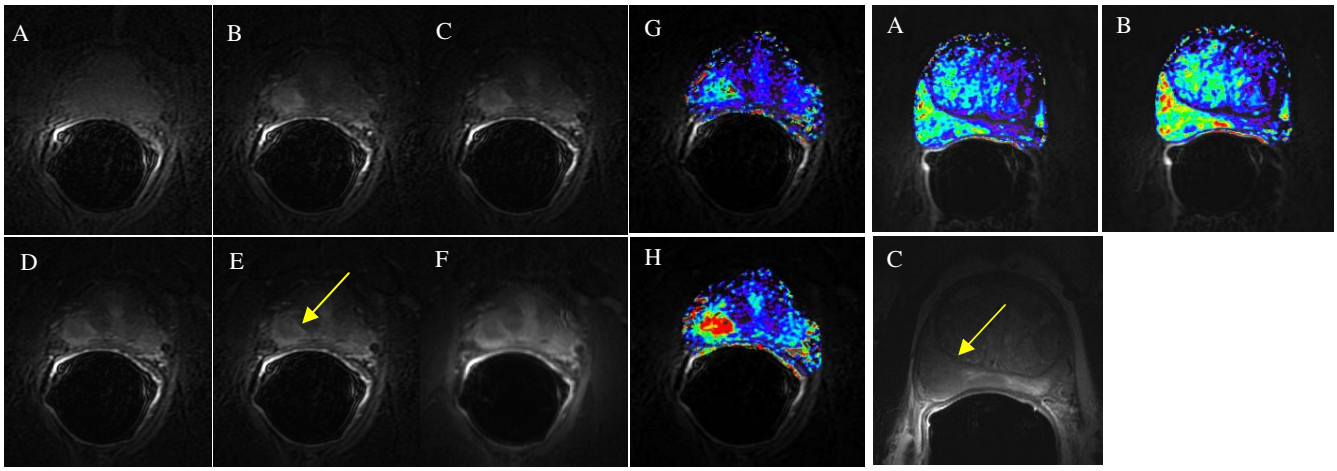

Figure 1. Precontrast phase (A) and four post contrast phases (B-E) corresponding to the ph 1, ph 5, ph 9, ph 13 obtained using the proposed 3D DCEMRI sequence with 3.5s temporal resolution demonstrate an enhancing mass (arrow) in the peripheral zone on the right. The image quality is similar to that of a late phase conventional 3D SPGR image (F). K^{trans} map (scale 0.5-4.5) using the high temporal resolution sequence (H) more clearly reveals the tumor than that of the low temporal resolution sequence (G). The lesion was proved to be prostate carcinoma after surgery.

Figure 2. Compared to K^{trans} map (scale 0.5-4.5) using the low temporal resolution version (A), the high temporal resolution map (B) more clearly depicts a biopsy proved prostate carcinoma, which corresponds to a large hypo-intense mass (arrow) in the peripheral zone on the right in the T_2 FSE image (C). The patient received androgen deprivation therapy and follow-up MRI in three months was scheduled.