Ultra Short Gradient Echo Imaging of the Prostate at 7T

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INTRODUCTION: The purpose of this study was to investigate, for the first time, the potential of ultra short TE (UTE) imaging the prostate at 7T, using a 3D radial acquisition of gradient echoes (UTE-GRE) (1). There are several unique characteristics of this sequence which create both challenges and opportunities for body imaging at 7T. First, UTE-GRE acquisitions would greatly reduce the tremendous field-dependent T2* effects. This has been shown to be a significant issue during the bolus passage of paramagnetic contrast agents (CA) as demonstrated in previous studies (2). These short T2* values can completely obscure the characteristic peak of the arterial input function as well as reduce the tissue contrast enhancement curves when measured with standard T1-weighted gradient echo acquisitions. Second, as there is effectively no spatial localization for this radial sequence, potential artifacts exist from moving tissue distant from the region of interest, thus requiring large volumes to be spatially encoded. However, if artifacts can be avoided the sequence provides large coverage which reduces in-flow artifacts and isotropic resolution which is beneficial for reformatting and coregistration with anatomic or other functional acquisitions. In this paper, we investigate both static and dynamic versions of the sequence for anatomic and contrast-enhanced studies of the prostate at 7T and discuss future directions for this novel imaging method.

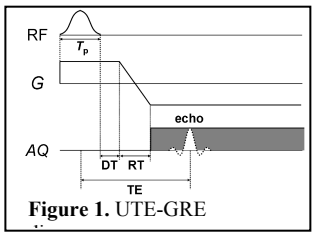

Figure 1. UTE-GRE

METHODS: The MRI system used for this study included a Magnex 7T, 90cm bore magnet with Siemens console and whole body gradients. An external 16 channel stripline array was used for RF transmission (3) of which 15 channels were used for receive in combination with a receive-only endorectal (ERC) coil (4). For transmit, a series of 16, 1 kW amplifiers (CPC, Pittsburgh, PA) were optimized for transmit efficiency in the region of the prostate (5) while power monitoring allowed FDA guidelines on local SAR to be followed. Limits on power were based on previous FDTD modeling studies (6).

Imaging data were collected on healthy volunteers (N=4, GFR > 60) under an IRB-approved protocol. After initial scouts, B0 shimming and B1+ shimming, axial T2w anatomic TSE images were acquired for visualization of anatomy and planning. For DCE-MRI, a single dose (0.1 mmol/kg) of Gd-DTPA (Magnevist, Berlex Laboratories) was delivered by an automatic hydraulic injector (Empower MR, Acist Medical) at a rate of approximately 3 cc/sec followed by a 20 ml saline flush.

The basic sequence diagram of the UTE-GRE sequence used for the DCE-MRI acquisition is shown in Fig. 1. Briefly, a phase-modulated hyperbolic secant (HS) pulse is used to excite a low tip angle in the presence of a gradient which defines a spoke of this 3D radial acquisition. After excitation, this (slab-selective) gradient is inverted to create an echo for readout. Acquisition begins as soon as the gradient fully ramps up to the readout plateau. Radial samplings are arranged with isotropic angular spacing to cover a sphere in k-space, having a spiral shape of view orders (7). The HS pulse had the following parameters: pulse length (T_p) = 0.25 ms, pulse bandwidth = 124.8 kHz, and a nominal flip angle in the prostate of 5°. The ramp time (RT) was set to be 0.06 ms, DT = 0 ms, resulting in a minimum TE of 0.31 ms which was used in these acquisitions. The spherical field-of-view (= slab width) was 40 cm. An anatomical acquisition was acquired with 16 spiral interleaves each with 6000 points and NEX = 1 giving a total of 96000 unique views. For dynamic imaging 16 spiral interleaves each with 1000 radial views with a single average and a total of 8 dynamics were acquired each taking 42 s resulting in a total scan time of 5:35. The nominal acquisition bandwidth was 124.8 kHz, with 2 times oversampling (Siemens default mode). 12 points were acquired before the center of the echo and 384 points where acquired after the echo center, both of these with 2 times oversampling. To reconstruct the asymmetric echoes, each projection was gridded onto a Cartesian grid using a Kaiser-Bessel kernel of width 4, and corrected with the grid ones density weighting (8). Gridding was performed with 1.5 times oversampling onto a 900x900x900 matrix and performed with in-house developed code. After gridding the k-space was Fourier transformed, apodization corrected and cropped to the nominal matrix.

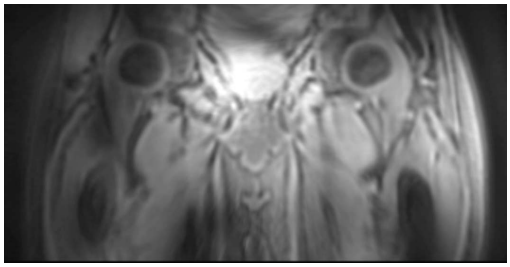
Figure 2: Cropped coronal view of the volumetric dataset.

RESULTS: The anatomic acquisition is shown in Fig. 2 reformatted in the coronal plane. The image is restricted in FOV to the sensitive region of the external stripline array coil. Figure 3 shows pre-contrast (dynamic 1) and post-contrast (dynamic 5) UTE-GRE images in both the axial and coronal planes along with high resolution T2-weighted TSE images for delineation of prostate anatomy. The two UTE-GRE planes are reconstructed from the same data to demonstrate the isotropic nature of the source data. The yellow arrow on the axial planes shows the internal iliac artery where the arterial input function is often defined for pharmacokinetic modeling.

DISCUSSION: The radial sampling scheme (view orders) employed in this study works well for anatomic imaging but was suboptimal for obtaining high temporal resolution DCE-MRI acquisitions. Therefore, while the current acquisition greatly reduces T2* signal loss, the large and early peak enhancement is not observed. This is a function of the acquisition strategy and subsequent sliding window reconstruction which has the effect of blurring the time course. Using the same basic sequence but optimizing the view ordering in a random manner, higher temporal resolution studies will be possible. Such an acquisition would lend itself to HYPR and compressed sensing reconstructions which have been shown to accurately reproduce time courses with sparsely sampled data (9). Finally, another potential benefit of this UTE-GRE implementation results from the large coverage imposed by the lack of overall volume selection. Exciting spins in a large volume will reduce the issue of in-flow effects which typically confound attempts to obtain reliable input functions for pharmacokinetic modeling.

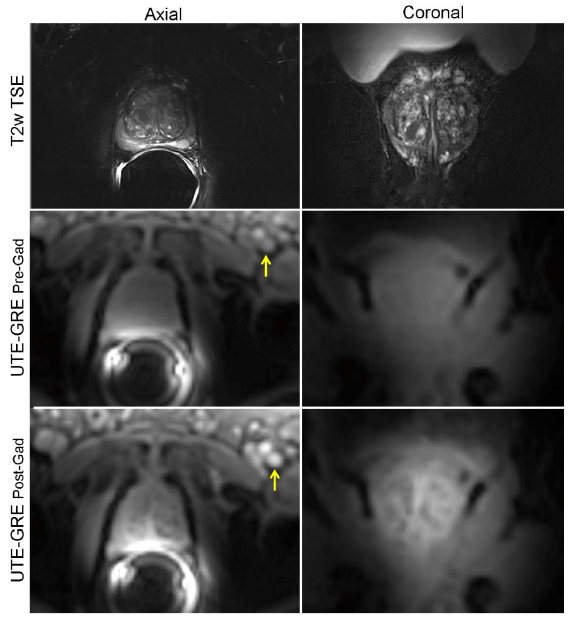

Figure 3: Comparison of pre and post contrast UTE-GRE.

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