Whole-Prostate T2 Mapping in Under 6 Minutes Using Autocalibration and Partial-Fourier MRI

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INTRODUCTION: T2-weighted MRI has been successfully used in prostate oncology to identify the lower T2 valued tumor tissue with very high sensitivity and low specificity [1,2]. Therefore, a typical MR exam for prostate cancer consists of multi-parametric MRI including T2-weighted MRI, ADC mapping and dynamic contrast enhanced MRI [1,2]. A clinically feasible T2 mapping technique is essential to develop a quantitative MR imaging framework for prostate oncology [3]. While parallel imaging techniques based on coil sensitivity profiles can be used to shorten the data acquisition times, acceleration factors are limited, as majority of signal over prostate in prostate MR images comes from the commonly used endo-rectal coil [4]. This work proposes a novel image acquisition and image reconstruction protocol which exploits the temporal redundancy in the multi-echo fast spin-echo (ME-FSE) imaging sequence used for T2 mapping along with coil sensitivity profiles and partial-Fourier MRI to generate T2 maps over the whole prostate in a clinically feasible scan time of less than 6 min.

THEORY: The proposed fast imaging technique combines the accelerated fast T2 mapping technique proposed in ref [5, 6] with partial-Fourier MRI to further reduce the data acquisition time.

Data acquisition: A ME-FSE imaging sequence is performed to estimate T2. The sub-sampling in the proposed technique is similar to the accelerated T2 imaging technique [5, 6] with sub-sampling of k-space data for each echo and, complete k-space acquisition near k=0 for calibration. The high k values in the negative half of the k-space are not acquired according to the partial-Fourier factor.

Image reconstruction: Image reconstruction for the proposed technique is performed as a two step process on the clinical scanner using modified SW. First the missing phase encoding lines in the acquired positive half and in central k-space are estimated by exploiting the temporal redundancy along the echo time direction in the ME-FSE MR images. These Missing phase encoding lines are estimated by weighted linear combination of the neighboring k-space lines and the weights for the linear combination are estimated from the central calibration data as described in ref [5, 6]. Then the missing negative half of the k-space is determined by estimating the phase from the central k-space followed by a homodyne reconstruction [7] to generate multi-echo MR images from each coil. The images from multiple coils are then combined by a SENSE reconstruction with reduction factor 1 [8].

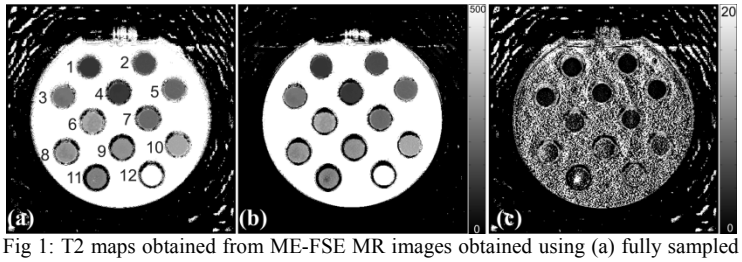

Fig 1: T2 maps obtained from ME-FSE MR images obtained using (a) fully sampled data and (b) proposed technique. The difference between the two is shown in (c)

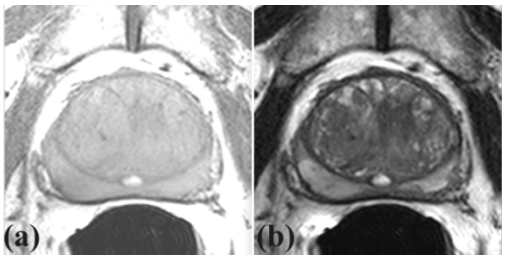

Fig 2: Axial mid-section slice of the patient number 3 (in Fig 3) prostate at TE of (a) 22ms and (b) 121ms.

T2-Mapping: T2 maps from the multi-echo MR images are estimated using a maximum-likelihood estimator (MLE) [9] to account for the Rician noise characteristics at longer echo times.

METHODS AND RESULTS: ME-TSE based T2 mapping was performed on a reference phantom with 12 vials with various T1/T2 values (Eurospin TO5, Diagnostic Sonar, Livingston, Scotland) and on 8 patients using a 3T clinical MR scanner (Achieva, Philips Healthcare, Best, NL). This study was approved by the local institutional review board (IRB) and was compliant with the Health Insurance Portability and Accountability Act (HIPAA); informed consent was obtained from each patient. The scans were performed with the anterior half of a 32-element cardiac phased array surface coil and a single channel endo-rectal coil. 24 slices were scanned using multiple interleaved 2D ME-FSE scans (number of echoes=16; TE_1=22ms; ΔTE=11ms; TR=2693ms; spatial resolution $0.80\times0.80\times2.73mm^3$, slice gap = 0.27mm, FOV=256x256mm^2, acq. matrix = 320x320) to cover the whole prostate. Odd numbered slices were first acquired together followed by the even numbered slices to avoid cross-talk between the slices. A partial-Fourier factor of 0.65 with k-space reduction factor of 4 was used for data acquisition. 16 phase encoding lines around the center of k-space were used for calibration resulting in a net acceleration of 4.9. A fully sampled ME-TSE MR dataset for T2 mapping of the phantom was obtained to compute a reference T2 map.

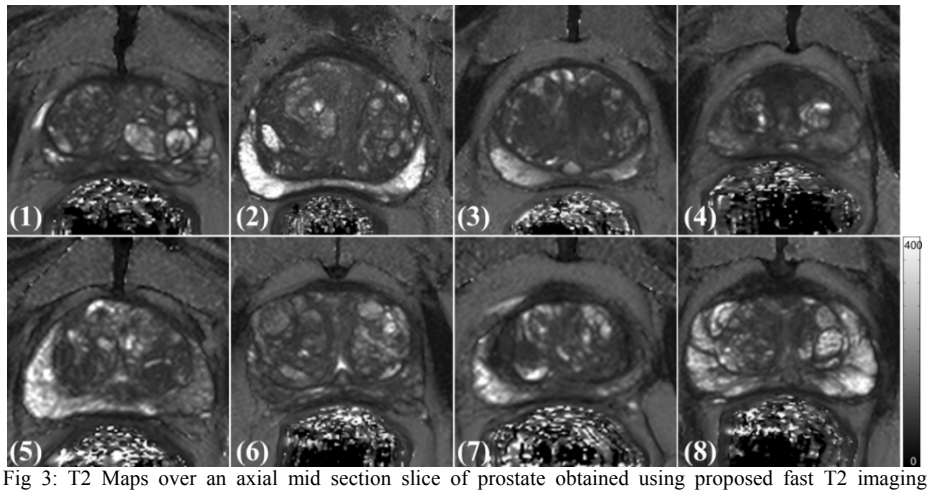

Fig 3: T2 Maps over an axial mid section slice of prostate obtained using proposed fast T2 imaging technique over 8 patients.

RESULTS AND DISCUSSION: The reference T2 maps and the T2 map obtained from the proposed fast T2 imaging technique over a slice of the phantom are shown in Fig. 1(a) and (b), respectively. While a very small amount of fold-over artifact can be seen on the error map shown in Fig 1(c), the majority of the difference is due to noise in the data as seen in the T2 value estimated over 12 vials marked in Fig 1 in Table 1.

All the patients were successfully scanned and T2 maps were obtained using the proposed fast T2 technique. The MR image of an example patient image at TE = 22ms and TE=121ms are shown in Fig 2(a) and (b), respectively, with no visible signs of fold-over artifacts. The high resolution T2-maps depicting small structures in prostate over mid axial slices of the 8 patients are shown in Fig 3.

CONCLUSION: We have successfully demonstrated a clinically feasible image acquisition and image reconstruction protocol for high resolution ($0.8x0.8mm^2$) T2 mapping of the prostate over 8 patients. The direct T2 reconstruction on a clinical scanner is improving the ease-of-use. The accuracy of the T2 maps obtained using the under-sampled data was shown in a phantom. The proposed technique decreases the scan time by a factor of 4.9 as compared to 3.7 as previously achieved without the partial-Fourier technique [6] and may critically support quantitative multi-parametric MR analysis for prostate oncology.

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Vial number	1	2	3	4	5	6	7	8	9	10	11	12
Reference	52.4±0.5	72.5±1.06	109.6±2.2	54.1±0.5	98.7±2.9	149.6±7.8	100.1±2.3	135.0±6.3	140.3±2.6	159.5±1.9	132.2±3.0	380.4±15.6
Accelarated	52.8±1.0	73.1±1.2	110.7±2.8	54.3±1.2	99.4±2.9	150.7±8.7	100.8±3.1	134.40±8.2	140.6±6.5	159.7±5.3	132.8±7.4	386.2±37.5

Table 1 : T2 value (in ms) estimated over 12 vials marked in Fig. 1.