Fast T_2 Relaxometry in Prostate Cancer Patients at 3T

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INTRODUCTION

Measurements of tissue T_2 values throughout the prostate gland may prove of value in discriminating cancer from healthy tissues (1), especially for computer aided diagnosis with multi-parametric MRI. Furthermore, T_2 mapping will allow investigators to perform longitudinal studies and inter-scanner and intra-scanner comparisons. The standard spin-echo measurement with different TEs for T_2 mapping is associated with long scan durations making this method impractical for most clinical applications. A fast variation, the multi-echo spin-echo experiment, has to be repeated with different phase-encoding gradients, until the entire *k*-space has been covered, still resulting in long acquisition time. An accelerated T_2 relaxometry was developed previously to reduce the number of phase-encoding steps in a multi-echo spin-echo measurement without loss of spatial resolution and dynamic range (2,3). In order to differentiation among prostate cancer patients, the proposed method was applied to characterize T_2 of prostate cancer and healthy peripheral zone tissues in men.

METHODS

Theory: *k*-space data at each echo time were undersampled similar to *kt*-BLAST (4) as shown in Figure 1 (for an undersampling factor of R =2). Only one in every *R* phase-encoding steps (black lines) was acquired at each echo time skipping the rest of the phase-encoding steps (blue lines). The position of the measured *k*-space line was shifted from one echo time to the next to achieve a better coverage of *k*-space over time. A number of blocks consisting each of *R* consecutive *k*-space lines without undersampling (red lines) were acquired for calibration purposes, preferably in the centre of *k*-space. To avoid fold-over artifacts due to undersampling, the missing *k*-space samples were first estimated by exploiting the linear correlation between the *k*-space samples at consecutive echo times. The proposed linear estimation scheme is illustrated for $R = 2$ and a $3 \times 3 \times 3$ neighborhood size in Figure 1 with each missing sample (black circle) estimated by a linear combination of its neighbors in the *kt*-space (black crosses).

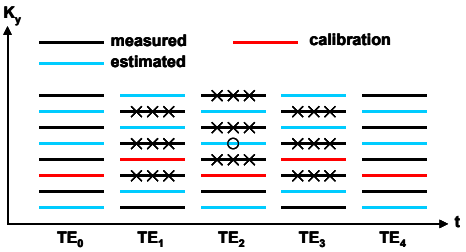

Figure 1. Undersampling pattern used for fast T_2 measurement (R = 2). The crosses represent the samples involved in the reconstruction of the missing sample (circle).

MRI: Prostate MRI scans including a regular T_2-weighted, ADC map, 3D Spectroscopic Imaging, T_2 mapping and DCE-MRI were performed on 23 patients using the 16-channel anterior half of a 32-channel SENSE cardiac array (Invivo, Orlando, FL) in combination with an endorectal coil (BPX 30, Medrad, Warrendale, PA) on a 3.0 T whole-body scanner (Achieva, Philips Healthcare, Best, the Netherlands). The prostate T_2 maps were acquired with an acceleration factor of $R = 4$ with 16 calibration lines with the following parameters: resolution = 1.09 mm × 1.09 mm × 3 mm, TR = 2200 ms, 16 echoes with TE = 30, 45, 60, … , up to 255 ms. The total scan time was about 10 minutes for 16 slices. A reproducibility study was performed in another 5 patients with two T_2 mapping scans separated by 25 ~ 30 minutes without repositioning the patient.

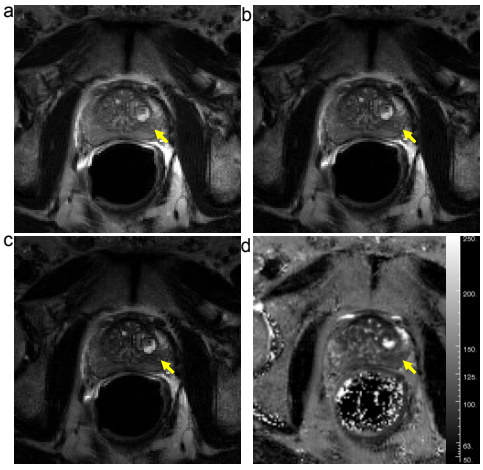

Figure 2. Reconstructed images at TE = 45ms (a), TE = 75 ms (b), TE = 105 ms (c) and the corresponding T_2 map. Yellow arrows indicate a tumor area.

Data Analysis: T_2 relaxation times were calculated with monoexponential curve fitting using Philips research software. T_2 maps were reviewed by a radiologist, together with T_2-weighted, ADC map and DCE-MR images. Prostatectomy specimens were reviewed by 2 pathologists who were blinded to the MRI. Prostate was divided in to six segments as left base (LB), right base (RB), left middle (LM), right middle (RM), left apex (LA) and right apex (RA). Tumor ROIs were drawn manually on T_2 maps on areas identified by the radiologist as lesions and confirmed by biopsy. Normal ROIs were drawn on the segments free of tumor lesions.

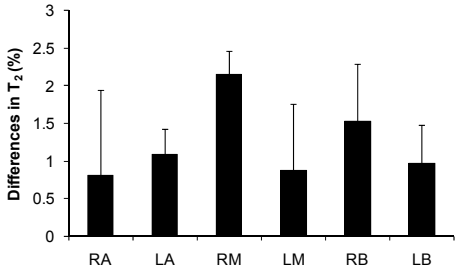

Figure 3. Reproducibility of the fast T_2 mapping.

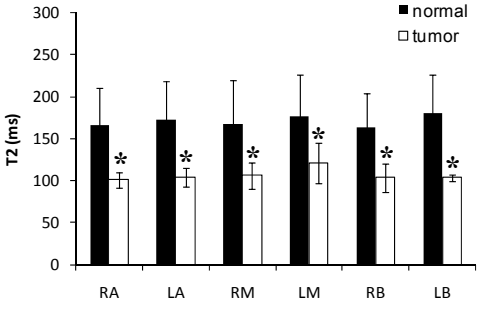

Figure 4. T_2 of tumor and normal tissues in prostate patients (*p<0.05).

RESULTS

Figure 2 illustrates the reconstructed images acquired at TE = 45 ms, TE = 75 ms and TE = 105 ms (a-c). Visually no folding artifacts can be seen on these four-fold undersampled images with yellow arrows indicating a tumor area. The conspicuity of this lesion varies with the degree of T_2-weighting with the greater conspicuity occurring at later echoes. Figure 2d illustrates the corresponding T_2 maps generated from the data set. The reproducibility of the fast T_2 relaxometry was illustrated in Figure 3. The differences of two scans in 5 patients ranged from 2.15 ± 0.31% to 0.80 ± 1.14% in the six segments. 16 out of 23 patients had biopsy proven adenocarcinoma with Gleason scores ranging from 6 (3+3) to 7 (4+3). The T_2 values of the tumor zones were significantly lower than the corresponding tissues as shown in Figure 4.

CONCLUSION

A fast T_2 mapping technique with four-fold undersampling has been applied to characterize prostate T_2 values in 23 patients. With *kt*-reconstruction utilizing the temporal and spatial correlation of T_2 signal decay, folding-free images were reconstructed at each echo time providing a series of diagnostic images with variable T_2-weighting. Quantitative T_2 maps were generated with very good reproducibility in clinical relevant scan time. T_2 values of tumor tissues were significantly lower than the normal control regions. Our results demonstrate this fast T_2 relaxometry can provide an effective approach for accelerated T_2 quantification in prostate patients.

REFERENCES

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