Relaxation along fictitious field, diffusion weighted imaging, and T_2 mapping of prostate cancer: correlation of quantitative values with Gleason score

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Purpose

To evaluate the performance of relaxation along fictitious field (RAFF) relaxation time (T_{RAFF}), apparent diffusion coefficient (ADC_m), and T_2 relaxation values for prostate cancer (PCa) detection and characterization.

Methods

Fifty-one patients (mean±SD age 63±7 years, mean±SD PSA 11.1±7.4 ng/ml) with histologically confirmed PCa underwent 3T MRI (Philips, Ingenuity PET/MR) examinations using 32 channel surface array coil and 2 channel volume whole body RF coil for RF transmission before radical prostatectomy. Repeated MR examination (T_{RAFF}, ADC_m) was performed in 17 patients following the first MR examination. T_{RAFF} was measured (1) with the pulse train durations of 0, 45, and 90 ms and the maximum radio frequency power of 11.74 µT. 3D T_1-FFE sequence was used as a read-out with the following parameters: TR/TE 4.0/2.3 ms, acquisition matrix size 168x144, reconstruction matrix size 384x384, slice thickness 5.0 mm, centric k-space coding, pulse interval 3000 ms. Diffusion weighed imaging data sets were acquired using a single shot spin-echo based sequence with monopolar diffusion gradient scheme, echo-planar read out, TR/TE 1394/44 ms, FOV 250x250 mm^2, acquisition matrix size 124x124, reconstruction matrix size 256x256, slice thickness 5.0 mm, b-values 0, 100, 300, 500 s/mm^2. T_2 relaxation values were measured using GraSE sequence with TR/TEs of 686/20, 40, 60, 80,100 ms, FOV 230x183 mm^2, acquisition matrix size 256x163, reconstruction matrix size 512x400, slice thickness 5.0 mm. Furthermore, T_2-weighted images (T2wi) were obtained using a single shot TSE sequence. The RF field homogeneity (B_1 field) was evaluated using actual flip angle imaging method (2) with TRs/TE 30,150/2.2 ms, flip angle 60 degrees, FOV 400x400mm^2, slice thickness 6.0 mm. Using whole mount prostatectomy sections and anatomical T2wi as reference, one ROI (square of 4.56x4.56x5.00 mm^3 for T_{RAFF}; square of 4.89x4.89x5.00 mm^3 for DWI; square of 4.93x 4.93x5.00 mm^3 for T_2) was placed in the center of PCa area and the same sized ROI in the peripheral zone (PZ), and central gland (CG) not containing PCa. Mean signal intensity (SI) of each ROI was fitted using two parameter monoexponential functi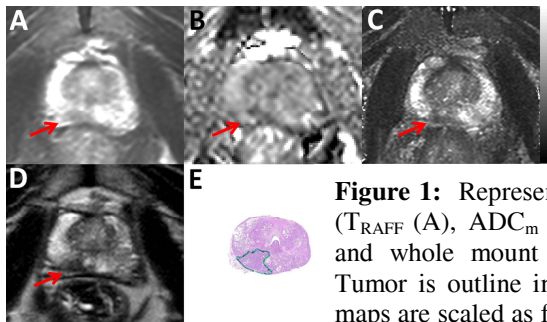on for RAFF and T_2 data. Apparent diffusion coefficient values (ADC_m) were calculated in a similar manner, fitting two parameter monoexponential model to mean DWI signal decay of each ROI. Short term repeatability was evaluated by means of Intraclass Correlation Coefficient (ICC) values, specifically ICC(3,1). Receiver operating characteristic curve analysis, area under the curve (AUC) values, was used to evaluate ability of T_{RAFF}, ADC_m, and T_2 relaxation time to discriminate PCa from normal tissue and to correctly classify PCa into Gleason score groups (low: 3+3, intermediate: 3+4, high: >3+4). Spearman correlation coefficient (ρ) was calculated between the parameters and Gleason score groups (n=3).

Figure 1: Representative relaxation time maps (T_{RAFF} (A), ADC_m (B) and T_2 (C)), T2wi (D) and whole mount prostatectomy section (E). Tumor is outline in green (E). The parametric maps are scaled as follows: T_{RAFF} (A) 0-200 ms, ADC_m (B) 0.0-3.0 µm/ms2, T_2 (C) 0-200 ms.

Results

T_{RAFF} and ADC_m demonstrated high repeatability with ICC(3,1) in the range of 0.68-0.92. AUC values for the differentiation of PCa from normal tissue were similar for all of the parameters and were in the range from 0.87 to 0.89 (Figure 1). Differences between tumors belonging to low and high Gleason score groups were statistically significant (p<0.01) for all of the quantitative parameters. In contrast, only T_{RAFF} values demonstrated statistically significant (p<0.05)

Figure 2: Box plots show T_{RAFF} (A), ADC_m (B), and T_2 relaxation (C) values of low, intermediate, and high Gleason score group tumors.

differences between intermediate and high Gleason score group tumors. Furthermore, RAFF method outperformed DWI and T_2 mapping in tumor classification based on AUC values. When all PCa ROIs were included, ρ (95% confidence interval) values for T_{RAFF}, ADC_m, and T_2 values were -0.68 (-0.81, -0.49), -0.56 (-0.74, -0.32), and -0.35 (-0.58, -0.07), respectively (Figure 2). The corresponding values for PZ tumors were -0.72 (-0.85, -0.51), -0.57 (-0.76, -0. 28), and -0.49 (-0.70, -0.19), respectively.

Conclusion Relaxation values obtained using RAFF method outperformed ADC_m, and T_2 relaxation time values in Gleason score classification of PCa tumors. **References** 1. Liimatainen T et al. Magn Reson Med 2010; 64:983-994; 2. Y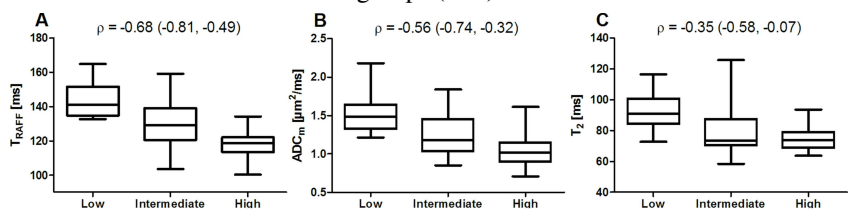arnykh VL. Magn Reson Med 2007; 57:192-200