Combined prostate DTI and DCE MRI at 3T – correlation with biopsy

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Introduction

We have previously shown in a study on a 1.5T MRI, that a combination of the Diffusion Weighted (DW) and Dynamic Contrast Enhanced (DCE) MRI provides higher sensitivity in diagnosing prostate cancer than each technique alone [1]. Here we present results from a similar study carried out on a 3T MRI scanner. We tested whether improved data quality, due to the higher field, improved sensitivities of the two MRI techniques to make it comparable to the sensitivity of the combined methods.

Methods

Twenty three patients with a high clinical suspicion for prostate adenocarcinoma due to an elevated PSA and/or palpable prostatic nodule with no prior treatment were recruited thus far to the study. Subjects underwent MRI examination prior to TRUS guided biopsies. From 8 to 12 needle biopsies were collected depending on the size of the prostate.

All MRI exams were carried out on a 3T Philips Achieva MRI scanner. Twelve axial slices (4 mm, no gap) across the prostate gland were acquired for both Diffusion Tensor Imaging (DTI) and DCE MRI data with FOV of 24 cm. DTI MRI data was acquired using a single shot EPI sequence (128x115, 6 directions, b-value=600). DCE MRI was performed using a 3D T_1-weighted spoiled gradient echo sequence: 256x163, TR/TE=3.4/1.06 ms (T1W) or 50/0.95 ms (PD), flip angle = 15^0 (T1W) or 4^0 (PD), and the time resolution of 10.6 sec per 12 slices. 75 time points were acquired following a bolus injection of Gd-DTPA (Magnevist, Berlex Canada, 0.1 mmol/kg within 10 s followed by a 20 ml flush of saline).

DTI data were processed using a proprietary DTI processing toolbox (Philips PRIDE). Diffusion weighted images were registered to one another prior to calculation and diagonalzing of the diffusion tensor. Average Apparent Diffusion Coefficient (ADC) and Fractional Anisotropy (FA) values were calculated from the ROIs defined as the hypointense areas in ADC maps. DCE data were processed with software procedures developed in house using Matlab (Mathworks, Natick, MA, USA) and Igor Pro (WaveMetrics, Portland, OR, USA). T_1-weighted (T1W) and Proton density (PD) images were registered to one another using proprietary registration toolbox (Philips PRIDE) based on a mutual information algorithm, prior to further processing. Arterial Input Functions (AIFs) were extracted from voxels in external iliac or femoral arteries in the central slice for each patient [2].Pharmacokinetic parameters (K^{trans}, extra-vascular extra-cellular space – v_e, plasma volume – v_p) were calculated by fitting the Gd concentration vs. time curves to the extended Kety model [3]. Average values of the modelling parameters were calculated from ROIs defined as hyperintense areas on K^{trans}. Control DTI and DCE parameter values were calculated from ROIs defined in the areas that were deemed normal based on both MRI and biopsy results. To correlate MRI with biopsy results, MRI data were mapped into biopsy maps according to the individual patient biopsy locations. Statistical analysis of differences between tumour, normal peripheral zone, and normal central gland was carried out using a Tukey-Kramer test.

Results and discussion

Five patients did not complete MRI scans. Seven of the remaining 18 patients have biopsies positive for carcinoma. Figure 1 shows representative K^{trans} (left) and ADC (right) maps from a patient with positive (top) and negative (bottom) biopsy. Average values of all MRI parameters (with the exception of extra-vascular extra-cellular space - v_e) showed significant differences between tumour and normal peripheral zone (see Table 1). Prostatic carcinoma in Table 1 correspond to the areas identified as prostate tumours with both MRI and histological data. Sensitivity and specificity of the DTI data were equal to 86% and 89% respectively. DCE data showed lower sensitivity of 66% but higher specificity of 94%. When both DTI and DCE results were combined the sensitivity increased to 91% while specificity lowered to 85%.

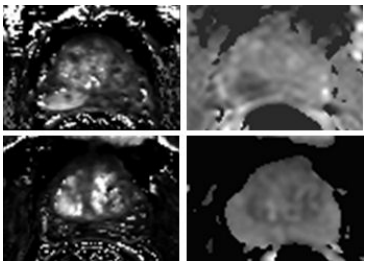

Fig. 1. K^{trans} (left) and ADC maps (right) for a patient with biopsy proven adenocarcinoma in right peripheral zone (top) and a patient with negative biopsies (bottom).

Table 1. Average values (mean ± SD) of DTI and DCE MRI parameters

	ADC $[10^{-3}mm^2/sec]$	FA	K^{trans} $[min^{-1}]$	v_e
PZ	1.85± 0.20	0.17 ± 0.05	0.04 ± 0.02	0.25 ± 0.07
CG	1.61 ± 0.11[a]	0.20 ± 0.04[c]	0.07 ± 0.03[c]	0.34 ± 0.10[a,d]
PCa	1.13 ± 0.15[a,b]	0.23 ± 0.12[c]	0.09 ± 0.03[a]	0.21 ± 0.05

PZ – peripheral zone, CG – central gland, PCa – prostatic carcinoma
a – significantly different than PZ ($p<0.001$), b – significantly different than CG ($p<0.001$),
c – significantly different than PZ ($p<0.01$), d – significantly different than PCa ($p<0.001$)

The results of our study confirms that both diffusion or DCE MRI can be used for the non-invasive detection of prostatic adenocarcinoma. The sensitivities of both methods increased substantially comparing to our earlier study at 1.5T (diffusion MRI from 54% to 86% and DCE MRI from 59% to 66% [1]). Increase in the field strength certainly was a significant factor. However, the data quality also improved by enhancing data processing techniques, namely: motion correction through image registration and improved pharmacokinetic modeling by measuring individual Arterial Input Functions. Unlike previously, in the current study we used DTI rather than DW MRI. Like before, the mean diffusivity (ADC) is significantly smaller in the tumour as compared to normal prostatic tissue. Our results also showed that FA is higher in the tumour than in the normal peripheral zone. This result is somewhat surprising, as one would expect that the chaotic cellular structure typically associated with tumours would result in a lower FA value. Our FA values in the normal peripheral zone and normal central gland correspond well to those previously published [4]. One previous study showed no difference in FA between tumour and normal prostatic tissue [5], while another showed lower FA values in the tumour comparing to the normal peripheral zone [6]. These discrepancies demonstrate that further investigation is needed to explain this issue.

In conclusion, all experimental parameters measured with DTI and DCE MRI, with the exception of extra-vascular extra-cellular space v_e, show significant differences between carcinoma and control peripheral zone. Sensitivity of both techniques increased compared to 1.5T. Combining both techniques provides better sensitivity with a small decrease in specificity.

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