High-Resolution Diffusion-Weighted Imaging for the Diagnosis of Prostate Cancer

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Introduction

An early detection of prostate cancer is essential to reduce mortality rates. In the past years, several studies have shown that diffusion-weighted imaging (DWI) can differentiate tumor from normal peripheral zone [1-3]. Most of these studies have applied single-shot spin-echo EPI due to its high SNR-efficiency and its insensitivity to motion artifacts. However, susceptibility-induced artifacts and T_2*-blurring limit the achievable resolution so that focal tumors might not be detected. Recent studies have addressed these problems using parallel imaging methods [3, 4]. However, the thereby achievable resolution is limited by spatial inhomogeneous noise amplification at high reduction factors.
The present work demonstrates that a spatially reduced FOV can achieve submillimeter in-plane resolution for prostate cancer DWI. The technique is tested in a clinical study and the findings are compared with biopsy results as the gold standard.

Subjects and Methods

DW images were acquired using single-shot spin-echo EPI with a reduced FOV in phase-encode direction. Similar to parallel imaging methods, the echo train length is thereby effectively reduced leading to decreased susceptibility-related distortions and image blurring. However, the g-factor penalty that is associated with parallel imaging methods can be avoided. Aliasing artifacts were circumvented by a non-coplanar application of the spin-echo pulses in combination with outer-volume suppression [5, 6].
25 patients (mean age = 65 years, range = 54 – 79 years) that were suspected to suffer from prostate cancer due to an elevated PSA level (mean PSA-level of 36 ± 92.5 ng/ml, range: 4.57 – 453 ng/ml) were investigated after informed consent. All patients underwent TRUS-guided systematic octant biopsy after MR-imaging. In addition, 13 controls were scanned (mean age = 55 years, range 40 - 75 years). The volunteers did not have any symptoms of prostatic disease and they had normal appearing MR images. Imaging was performed on a 3 T Philips Achieva (Philips Healthcare, Best, the Netherlands) using a cardiac coil array. Transverse DW images (b = 0 s/mm^2 and b = 500 s/mm^2, 30 DW directions) were acquired with the following parameters: acquisition matrix = 85 x 256, FOV = 60 x 180 mm^2, partial Fourier = 0.6, slices = 12, slice thickness = 5 mm, TE = 52.7 ms, TR = 2500 ms, 15 signal averages at the lower, 3 at the higher b-factor. The total scan time was 13 min 30 s. Moreover, transverse T_2-weighted images (TE = 100 ms, TR = 5000 ms) were acquired over the same volume but with twice the number of slices. The apparent diffusion coefficients (ADC) and the fractional anisotropy (FA) values were calculated using in-house software written in Matlab (The Mathworks, Natwick, MA, USA). Two separate diagnoses were made on the basis of the ADC maps and the T_2-weighted images by consensus reading of two blinded radiologists with 12 years of experience. Thereby, regions of interest (ROIs) were drawn separating tumor tissue from normal peripheral zone. Tumor tissue was identified as focal areas of hypointensity both on T_2-weighted images and ADC maps. The findings were then compared with biopsy results.

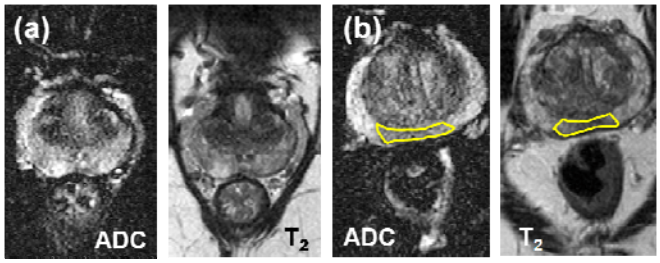

Fig. 1: Exemplary ADC maps and corresponding T_2-weighted images in a volunteer (Fig. 1a) and a patient (Fig 1b). The tumor is marked by the yellow ROI.

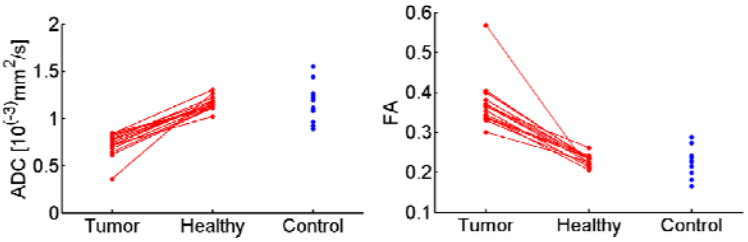

Fig. 2: Plots of the mean ADCs and FA values in the tumor and the normal peripheral zone of the patients. Additionally, the values in the peripheral zone of the volunteers are depicted.

	Sensitivity [%]	Specificity [%]
DWI	83.3	30.8
T_2 Imaging	83.3	38.5

Tab. 1: Sensitivity and specificity of the two imaging methods (DWI and T_2-weighted imaging) in relation to TRUS guided biopsy.

Results

The shortening of the readout train enabled DWI acquisitions with sub-millimeter in-plane resolution (0.7 x 0.7 mm^2) without the occurrence of susceptibility-related artifacts leading to ADC maps that feature fine anatomical details (Fig. 1). The mean ADCs in the tumor tissue of the patients were significantly lower, the mean FA values significantly higher, than in the surrounding healthy tissue (one-tailed paired t-test, $p < 0.05$). However, no threshold for malignancy could be established. Moreover, the mean ADCs and FA values were not significantly different in the healthy tissue of the patients and the control group (two-tailed t-test) (Fig. 2). The two imaging techniques (T_2-weighted and DWI) performed equally well in comparison with the biopsy results. Both methods feature high sensitivity but rather low specificity (Tab. 1). However, the outlines of the tumors were more clearly visible on the ADC maps.

Discussion and Conclusion

Reduced FOV single-shot EPI enables the acquisition of high-resolution DW images free of susceptibility-induced artifacts that show fine anatomical details. This enables accurate evaluation of diffusion parameters in localized structures of the prostate. As compared to T_2-weighted imaging, ADC and FA values provide directly quantifiable markers. In the light of the rather low specificity the combination with complementary imaging techniques like spectroscopic or dynamic contrast enhanced imaging is mandatory. The high sensitivity shows the potential of the technique; especially when considering the mostly low PSA values (15 patients had PSA values lower than 9 ng/ml) in the present study.

References: [1] Issa, B., [2002], JMRI, 16: 196-200. [2] Hosseinzadeh, K. et al., [2004], JMRI, 20: 654-661. [3] Sato, M. D. et al., [2005], JMRI, 21: 258-262. [4] Pickles, M. D. et al., [2006], JMRI 23: 130-134. [5] Wilm, B. J. et al., [2007], MRM, 57: 625-630. [6] Wilm, B.J. et al., [2008] NMR Biomed., in-print