Diffusion-weighted imaging of the prostate at 3T using high b-factors

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Introduction : Diffusion-weighted imaging (DWI) of the human prostate has demonstrated its potential clinical value for the detection of prostate cancer [1-2]. At 3T, only a few studies using a phased-array body coil instead of an endorectal coil have been reported [3-4]. In this paper, we investigate the use of diffusion-weighted imaging at 3T without endorectal coil and involving b-values superior to 1000 s/mm² . The aim of this study is to demonstrate the clinical value of DW imaging at 3T with high b-factors.

Methods : 31 patients (mean age : 62 years old) with elevated PSA level or suspicious digital rectal examination, underwent MRI on a 3T scanner (Philips, Best, The Netherlands), using the 6-channel cardiac coil for signal reception. Patients had a small enema before MR examination, in order to avoid susceptibility artifacts (responsible of spoiled lesion appearance) caused by the air inside the rectum (see example shown in Fig.1, before and after enema). The MR examination consisted of a 40sec TSE-T2 survey followed by respiratory-triggered DWI (single-shot DW-SE-EPI) : resolution 2.5x2.5x4mm³, TE=86 ms, NSA=4, Sense-factor 2 and spectral adiabatic inversion pulse for fat suppression. Five b-factors were used : 0, 1000, 1500, 2000 and 2500 s/mm². Then, a high-resolution (0.55x0.55x4mm³) respiratory-triggered T2-weighted imaging with the same geometry than DWI was performed (TE=135ms). T1-weighted imaging was also applied to detect possible hemorrhagic foci. ADCs were calculated with all five b-values, with b=1000 to 2500 and with b=0-1000 s/mm² only, and results were compared to histopathology (Transrectal Ultrasound "TRUS"-guided biopsies).

Results : Fig.2 shows a series of DW images, illustrating that at 3T the higher SNR allows to perform higher b-factors. Furthermore, it shows that with b>1500 s/mm², the lesion delineation is improved. Comparing DWI with the results of histopathology (TRUS-guided biopsies, systematically performed in 12 predefined sextants), we have obtained the following results : 14 true positives, 8 true negatives, 7 false positives (benign lesions) and 2 false negatives, i.e., sensibility = 87,5%, specificity = 53,3%, VPP = 66,7% and VPN = 80%. Table 1 gives the ADC calculations for central gland (CG), peripheral zone (PZ), malignant and benign lesions, performed for 3 different sets of b-factors : all b-factors (from 0 to 2500), from b=1000 to 2500 (i.e., b=0 excluded) and with b=0 and b=1000 s/mm² only. In all three cases, lesion ADCs are significantly different from ADCs of healthy tissue (t-student test : p<0.0001), however benign and malignant lesions could not be differentiated. Note that these ADC calculations are based on a monoexponential decay of the signal, which better fits the experimental data when b-values are restricted from 1000 to 2500 s/mm² (in this case ADC reflects diffusion only, without perfusion effects). Fig.3 illustrates graphically the ADC differences between healthy tissue and lesions, using b-factors from 1000 to 2500 s/mm².

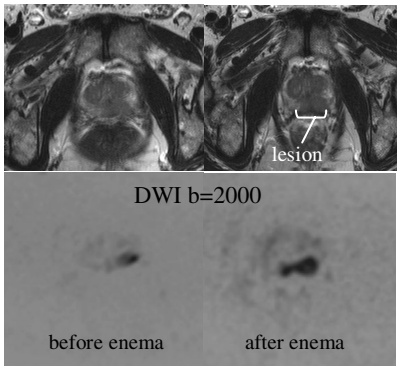

Fig.1 : T2 (top) and DW (bottom) images before and after enema (inverted windows), which improves the lesion conspicuity.

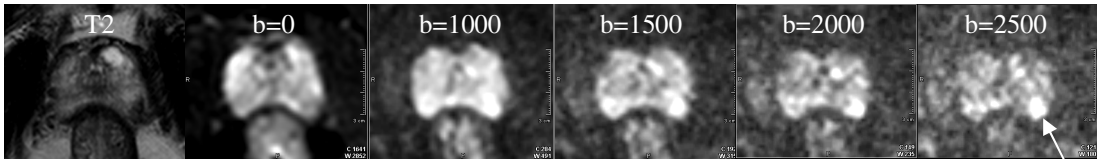

Fig.2 : T2 and DW images. At 3T, b-values up to 2500 s/mm² are achievable, providing improved lesion delineation. The malignant lesion (confirmed by biopsy) is indicated by the arrow.

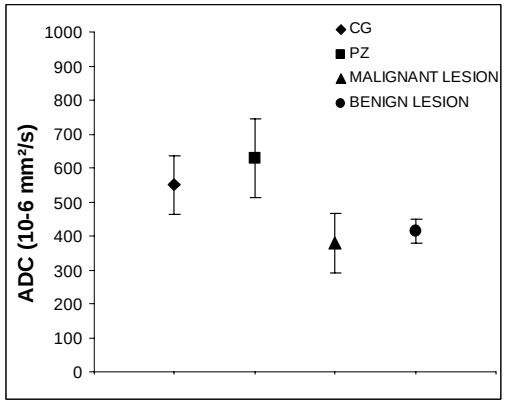

Fig.3 : Comparision of the ADC values (calculated with b=1000-2500 s/mm²) for CG, PZ, neoplasic and benign lesions. The ADCs of lesions are well separated from the ADCs of healthy tissue. However, benign lesions cannot be differentiated from malignant lesions.

ADC	all b-factors	b1000 to 2500	b0-1000
CG	919 ± 114	550 ± 87	1453 ± 191
PZ	1119 ± 176	628 ± 115	1826 ± 347
malign. lesions	585 ± 138	379 ± 89	868 ± 201
benign lesions	626 ± 66	414 ± 36	925 ± 138
t-test CG-lesions	p<0.0001	p<0.0001	p<0.0001

Table 1 : ADC values (unit : 10^{-6}mm²/s) for CG, PZ, malignant and benign lesions, calculated for 3 different sets of b-factors : all b-factors (from 0 to 2500), from b=1000 to 2500 (i.e., b=0 excluded) and with b=0 and b=1000 s/mm² only.

Discussion and conclusion : DW imaging of the prostate was successfully obtained at 3T without the use of an endo-cavitary coil. The high b-factors involved allowed to better delineate lesions. Because of the relatively high number of false positives, no threshold value of the ADC was established to characterize malignant lesions. Interestingly, for the 2 false negatives histopathology revealed microfoci including only a few glands. In conclusion, diffusion-weighted imaging of the prostate has a high sensitivity for the detection of suspicious lesions and should be considered to target biopsy sites.

References : [1] Tanimoto et al., JMRI 2007;25(1):146-52 [2] Kumar et al., NMR Biomed. 2007;20: 505–511
[3] Pickels et al., MRM 2006;23:130–134 [4] Miao et al., EJR 2007;61:297–302