Comparison of Quantitative T2 Mapping and Diffusion Weighted Imaging in the Normal and Pathologic Prostate

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Introduction
Over the past few years MR imaging of the human prostate has become increasingly prevalent. However, due to the similarity in signal intensity between prostatic carcinoma and benign prostatic hyperplasia (BPH) the usefulness of conventional MRI is debatable. T2 weighted FSE images appear to offer the greatest diagnostic accuracy [1]. Many authors have suggested the use of dynamic contrast enhanced imaging may improve this situation although current results are inconclusive [2].

Diffusion weighted imaging has been shown to be useful when studying stroke and ischaemia where changes in apparent diffusion coefficient (ADC) often precede changes in relaxation rates. The high correlation between ADC and T2 values in normal brain becomes compromised secondary to changes in extracellular volume and increased tortuosity [3].

This works aims to demonstrate the feasibility of diffusion weighted MR imaging of the prostate and to investigate the relationship between ADC and T2 relaxation rates in healthy volunteers and patients with prostatic pathology.

Methods
All imaging was performed using a GE 1.5 T scanner and a commercial pelvic phased array coil. Eight healthy volunteers aged between 24 and 34 years (mean 29 years) and 15 patients between 64 and 80 years (mean 69 years) were scanned. A single axial slice through the centre of the prostate was examined in detail.

Images with varying T2 weighting, to enable T2 calculation were obtained using an FSE sequence [4]. Images were obtained at 4 different echo-times (28, 56, 84, and 112 ms) in two separate acquisitions each of 5 minutes duration (TR 4 s, echo train length 8, field of view 19x19 cm, matrix size 256x128, slice thickness 7 mm, 2 avgs).

Diffusion weighted images of the same slice were acquired using a single shot echo planar imaging sequence (TR/TE 4000/110 ms, field of view 19x19 cm, matrix size 96x96, slice thickness 7 mm, 16 avgs). Images were obtained at 8 different diffusion weightings with gradient strength ranging from 0 to 21 mT/m in 3 mT/m steps, resulting in a scan time of 8½ minutes. The b-values ranged from 0-860 s/mm². Diffusion gradients were applied along each of the three main axes in turn to allow for subsequent trace calculation.

T2 and ADC values were then calculated from user defined regions of interest (ROIs) in the peripheral zone and central gland of each volunteer. For the patient data ROIs were drawn in BPH, prostatic carcinoma, and normal peripheral zone where available.

Relaxativity, R2 (1/T2) and ADC values were compared using scatter plots, linear regression analysis, and the Pearson correlation coefficient.

Results
Despite the long acquisition time involved the images were generally free of motion artifacts. No major susceptibility effects were noted within the prostate given the proximity of the rectum. Good quality fits were obtained for all diffusion (mean R² 0.90) and T2 data (mean R² 0.99).

Concerning the volunteer data T2 values were significantly higher in the peripheral zone (mean 122.2 ms) compared to the central gland (mean 88.2 ms) (p<0.015). ADC values were only significantly higher in the peripheral zone compared to the central gland for the x-gradient direction (p<0.029). However, inspection of the R2 values showed no significant correlation with ADC for all three gradient directions as well as the trace. A moderate correlation was noted between R2 and ADC in the z-direction for both peripheral zone (r=0.618) and central gland (r=0.579).

The patient data is summarized in Table I. Significant differences were noted between T2 values in tumour and peripheral zone (p<0.003) and between BPH and peripheral zone (p<0.027). No differences were noted between BPH and tumour T2 values (p>0.108). Comparing R2 and ADC values no significant correlations were found for tumour, BPH, and peripheral zone apart from between R2 and ADC in the y-direction (p<0.023).

Discussion
This work has demonstrated that it is possible to obtain accurate T2 and ADC values in the human prostate in reasonable scan times.

Other workers have demonstrated a correlation between T2 and ADC in normal brain tissue. Therefore it might be expected that this relationship can be extrapolated to other organs. However, this work has failed to demonstrate a correlation in the prostate of healthy volunteers. This could be attributed to the small study population but a more important factor may be the narrow age range of the volunteers which has resulted in a bunching of T2 values. However, to ensure only healthy tissue is considered, young volunteers have to be selected because of the increasing prevalence of occult BPH in the older population.

There appears to be no physiological reason why the only significant correlation in the patient data is between ADC in the y-direction and R2 for the peripheral zone. This result is no longer significant when an appropriate Bonferroni correction is implemented, since multiple comparisons are being made.

The absence of correlation between relaxation rates and apparent diffusion coefficients indicate that diffusion weighted imaging may offer further insight into disease processes in the prostate.

References

Table I: Correlation between ADC and R2 values for patient data.
Pearson correlation coefficients are shown along with associated P value in parenthesis.

<table>
<thead>
<tr>
<th></th>
<th>ADCx</th>
<th>ADCy</th>
<th>ADCz</th>
<th>Trace</th>
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<tbody>
<tr>
<td>Tumour</td>
<td>-0.098</td>
<td>-0.047</td>
<td>0.041</td>
<td>-0.064</td>
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<tr>
<td></td>
<td>(0.763)</td>
<td>(0.884)</td>
<td>(0.900)</td>
<td>(0.844)</td>
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<tr>
<td>BPH</td>
<td>0.215</td>
<td>-0.398</td>
<td>0.460</td>
<td>0.317</td>
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<tr>
<td></td>
<td>(0.579)</td>
<td>(0.289)</td>
<td>(0.213)</td>
<td>(0.372)</td>
</tr>
<tr>
<td>Peripheral Zone</td>
<td>0.523</td>
<td>-0.738</td>
<td>0.442</td>
<td>0.280</td>
</tr>
<tr>
<td></td>
<td>(0.149)</td>
<td>(0.023)</td>
<td>(0.234)</td>
<td>(0.465)</td>
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