Assessment of Different Quantification Approaches of DCE-MRI in Prostate Cancer at 3T

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Introduction
Prostate cancer detection in the transition zone is challenged by its high vascularity and the frequent occurrence of benign prostatic hyperplasia (BPH) [1]. Improving and advancing the non-invasive capabilities of cancer delineation might be achieved by dynamic contrast-enhanced MRI at high field. This study compared different quantitative approaches, in order to improve the differentiation of prostatic tissues imaged at 3T without using an endorectal coil.

Material and methods

Patients
27 patients (57 ± 5 years) with clinically proven prostate cancer were enrolled in this study.

MRI
All patients were imaged in a 3.0 Tesla MR system (Achieva, Philips) using an 8 phased-array coil. DCE-MRI was performed using a 3D T1-weighted fast field echo (3D-FFE) imaging sequence. The TIW-3D-FFE sequence (TR/TE = 7.6/3.9 ms; FOV = 220 x 220 mm²; matrix = 192 x 192; 20 slices; 3-mm slice thickness; 14.1 sec per volume) was applied to prostate cancer subjects. The extracranial Gd-based contrast agent (0.1 mmol/kg bodyweight, 0.5cc/sec) was intravenously injected by a power injector (Spectris®, MedRad) followed by a saline flush.

Histology
Regions of prostate cancer in 4 μm stained slices of the prostate and seminal vesicles (removed with robotic prostatectomy) were outlined by a pathologist.

Statistical Analysis
The Bonferroni test was used in SPSS 15.0 (SPSS Inc.) to compare the parameters in the histology identified tumor region and other regions. Statistical significance was considered at p <0.05.

Results
All marked tumor regions identified in histology were delineated in the DCE-MRI images (Figure 1a and 1b). The time-signal intensity curves from the ROIs enabled the calculation of the pharmacokinetic parameters to characterize perfusion in different tissues (Figure 1c and 1d).

Discussion and Conclusion
All parameters could differentiate tumor from the non-cancerous peripheral zone. Tumor perfusion showed faster wash-in (shorter $t_{max}$), higher enhancement (larger $MER$, Amp and $K_{trans}$), and faster washout (larger washout-score and $k_{ep}$) than non-cancerous PZ perfusion. However, only $t_{max}$, washout-score, $k_{Brix}$, and $k_{Larsson}$ could differentiate tumor from central gland. High washout-score and fast exchange rate $k_{ep}$ in the tumor region supports the high permeability of the vasculature and small extracellular space [4].

Figure 1. DCE-MRI of a prostate cancer patient. Color-coded parameter map (a) and pathology slice (b) show a tumor in posterior bilateral region with combined Gleason score of 3+4=7. The time-signal intensity curves from tumor, PZ, CG, muscle, and NVB are plotted in (c) and (d).

Figure 2. Boxplot of $t_{max}$ (a), washout-score (b), and $K_{Brix}$ (c) and $K_{Larsson}$ (d) in different regions. Region 1: tumor; Region 2: normal peripheral zone; Region 3: central gland; Region 4: muscle; Region 5: neurovascular bundle.

Table 1. Comparison of different DCE-MRI parameters in prostate cancer regions measured by Bonferroni Test

<table>
<thead>
<tr>
<th>Mean Difference</th>
<th>Semi-quantitative parameters</th>
<th>Adjusted Brix's Model</th>
<th>Larsson's Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$t_{max}$ Washout</td>
<td>$AUC_{60}$</td>
<td>$AUC_{90}$</td>
</tr>
<tr>
<td>Tumor vs PZ</td>
<td>0.72* -1.58*</td>
<td>16.69*</td>
<td>0.70*</td>
</tr>
<tr>
<td>Tumor vs CG</td>
<td>-0.21 -1.54*</td>
<td>16.53*</td>
<td>0.18</td>
</tr>
<tr>
<td>Tumor vs Mus.</td>
<td>2.06* -2.65*</td>
<td>21.82*</td>
<td>1.55*</td>
</tr>
<tr>
<td>Tumor vs NVB</td>
<td>0.59* -3.81*</td>
<td>20.75*</td>
<td>1.09*</td>
</tr>
</tbody>
</table>

*The mean difference is significant at the 0.05 level. PZ: non-cancerous peripheral zone; CG: central gland; Musc: muscle; NVB: neurovascular bundle.