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 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 T1W-3D-FFE sequence (TR/TE = 7.6/3.9 ms; FOV = 220 x 220 mm^2; matrix = 192 x 192; 20 slices; 3-mm slice thickness; 14.1 sec per volume) was applied to prostate cancer subjects. The extracellular 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.

Image Analysis Regions of interest (ROIs) were drawn on specific region, such as histology identified cancer regions (including tumors in peripheral zone and transition zone), non-cancerous peripheral zone (PZ), central gland (CG) including BPH, muscle and neurovascular bundle (NVB). The arterial input function (AIF) was defined as the time-signal intensity curve from the ROI drawn on the femoral artery.

1. Semi-quantitative parameters Five parameters were calculated: the maximum enhancement ratio (MER, [a.u.]), time to maximum signal enhancement (tmax, [min]), washout-score (the relative difference between the maximum signal enhancement and the signal intensity at the end of the dynamic scan), and the area under the curve during 60 seconds (AUC60, [min]), 90 seconds (AUC90, [min]) and 180 seconds (AUC180, [min]).

2. Adjusted Brix's model The adjusted model assumes that the exchange rates between blood plasma compartment and extravascular extracellular space (k_{pe}, k_{ep}) are much larger than the elimination factor in blood compartment, from which a bi-exponential decay function was used to fit the AIF [2]. From the adjusted Brix's model, Amp and contrast agent exchange rate (k_{pe} and k_{ep}) were obtained by fitting the tracer kinetics equation to the time-signal intensity curve.

3. Larsson's model The AIF was directly applied to the convolution integral equation and two parameters K^{trans}, and k_{ep} were calculated [3].

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).

Among the semi-quantitative parameters, t_{max} in the tumor region was significantly shorter than those in non-cancerous PZ ($p = 0.03$), CG ($p = 0.03$), muscle ($p < 0.001$), and NVB regions ($p < 0.001$) (Figure 2a). Washout-score in the tumor region was significantly larger than those in the other 4 different regions (p's <0.001) (Figure 2b). No significant difference existed between the tumor and central gland for parameter MER, AUC60, AUC90, and AUC180 as shown in Table 1. In adjusted Brix's model, k_{ep}^{Brix} in the tumor region was significantly greater than those in non-cancerous PZ ($p < 0.01$), CG ($p < 0.01$), muscle ($p < 0.01$), and NVB regions ($p < 0.001$) (Figure 2c). No significant difference was found between the tumor and CG or NVB for Amp and k_{pe}. In Larsson's model, $k_{ep}^{Larsson}$ in the tumor region was significantly greater than those in the other 4 different regions (p's <0.001) (Figure 2d). No significant difference existed between the tumor region and CG for K^{trans}.

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_{ep}^{Brix}, and $k_{ep}^{Larsson}$ 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].

In conclusion, DCE-MRI at 3T is capable of non-invasively detecting prostate cancer especially from the central gland by selecting appropriate parameters. The selected pharmacokinetic parameters provide a roadmap for prostate cancer detection and diagnosis without using an endorectal coil.

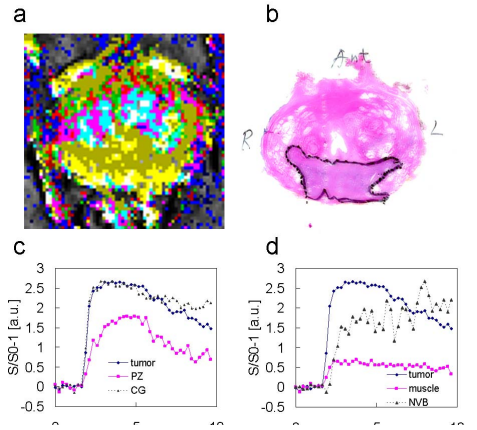

Figure 1. DCE-MRI of a prostate cancer patient. Color-coded parameter map (a) and pathology slice (b) show a tumor in posterior bilateral region with combined Gleason score of 3+4=7. The time-signal intensity curves from tumor, PZ, CG, muscle, and NVB are plotted in (c) and (d).

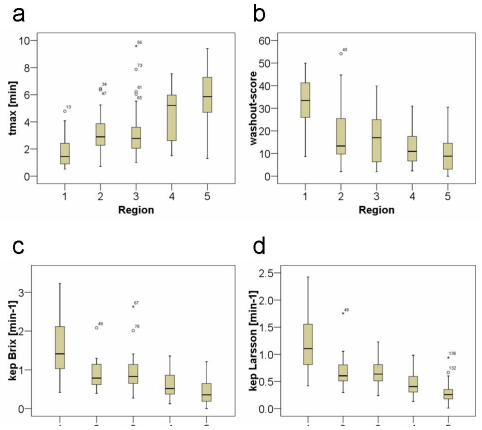

Figure 2. Boxplot of tmax (a), washout-score (b), and k_{ep}^{Brix} (c) and $k_{ep}^{Larsson}$ (d) in different regions. Region 1: tumor; Region 2: normal peripheral zone; Region 3: central gland; Region 4: muscle; Region 5: neurovascular bundle.

References

1. Engelbrecht MR, et al, Radiology 2003;229:248, **2.** Yang X, et al, Proc. ISMRM 2007;15:143, **3.** Larsson HB, et al, JMRI 1994;4:433; **4.** Alonzi R, et al, EJR 2007;63:335.

Table 1. Multiple Comparison of different DCE-MRI parameters in prostate cancer using Bonferroni Test

Mean Difference	Semi-quantitative parameters						Adjusted Brix's Model			Larsson's Model	
	MER	t_{max}	Washout	AUC60	AUC90	AUC180	Amp	k_{pe}	k_{ep}^{Brix}	K^{trans}	$k_{ep}^{Larsson}$
Tumor vs PZ	0.72*	-1.58*	16.69*	0.70*	1.08*	1.96*	0.84*	13.85*	0.72*	1.01*	0.59*
Tumor vs CG	-0.21	-1.54*	16.53*	0.18	0.15	-0.29	-0.11	9.45	0.69*	0.62	0.61*
Tumor vs Musc.	2.06*	-2.65*	21.82*	1.55*	2.54*	5.36*	2.25*	13.74*	0.80*	1.79*	0.81*
Tumor vs NVB	0.59*	-3.81*	20.75*	1.09*	1.64*	2.97*	0.58	10.64	1.19*	1.29*	0.98*

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