Analysis of Prostate DCE-MRI at 3T using a Measured Arterial Input Function

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Introduction

The ability to detect and identify malignant lesions within the prostate with conventional T_2-weighted imaging is still quite poor. Although lesion conspicuity is improved with dynamic contrast-enhanced imaging there still remains some ambiguity since all tissues with the prostate may enhance. The aim of the current study was to assess the ability of permeability maps to clearly delineate malignant areas within the peripheral zone.

Methods

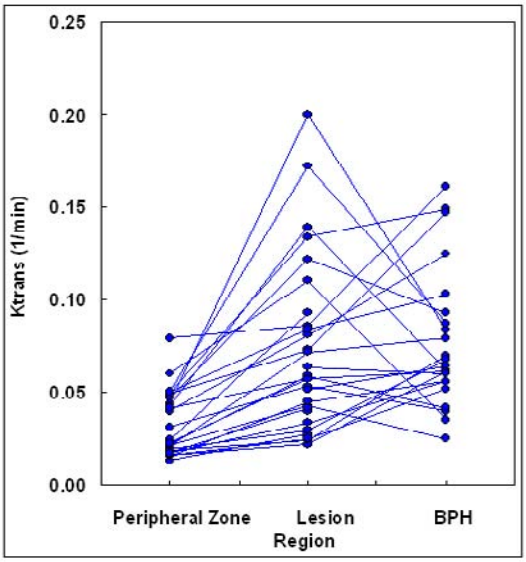
Twenty-eight consecutive patients with elevated PSA and biopsy confirmed prostate malignancy were referred for staging of their tumours. All were scanned at 3T on a GE Signa Infinity using an 8-element torso phased-array receiver coil. The following image series were acquired: sagittal T_2W FSE localiser, low resolution axial T_2W FSE to assess nodes and distant metastases, ASSET calibration, high resolution axial and coronal T_2W FSE to assess the gland and surrounding structures, three axial 3D FSPGR series at 2^o, 10^o & 28^o flip angle and finally a dynamically-acquired, multi-phase axial 3D FSPGR with 28^o flip angle. Contrast, 0.05 mMoles.kg^{-1} of Gd-DTPA, was pump-injected at 4 ml.s^{-1} after 17 s of scanning. All FSPGR series were acquired over a 300mm x 300mm FOV with a 256 x 128 matrix and 24 locations per slab. With TR = 5.35 ms, TE = 2.1 ms and an ASSET factor of 2 we were able to achieve a temporal resolution of 8.36 s per volume thus providing 35 samples in 4'45".

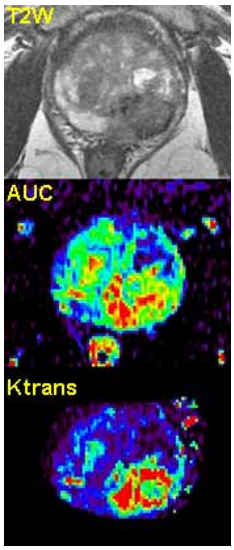
Pharmacokinetic parameters were obtained for hand-drawn ROIs in lesion, BPH and apparently normal peripheral zones using the following scheme. First, signal intensity changes at each time point were first converted to [Gd] with the relationship $[Gd] = (1/T_{1,t} - 1/T_{1,0}).\Re^{-1}$ using T_1 values obtained from the multiple flip angle FSPGR data and a gadolinium relaxivity ($\Re$) of 5.8s^{-1}.mM^{-1} (determined for 3T in separate experiments *in vitro*). The concentration time course was then iteratively deconvolved from the arterial input function (AIF) to obtain a tissue impulse-response function that was fitted to the expression $IRF = K_{trans}.\exp(-K_{trans}/V_e.t)$. For the AIF we used the [Gd] time course obtained from an ROI placed centrally within the left femoral artery. All processing was performed interactively on a SunBlade 2000 workstation using software developed in IDL.

	Peripheral zone (30)	Tumour (32)	BPH (23)
T_1 (s)	2.54 ± 1.41	2.05 ± 0.70	2.40 ± 0.73
Max [Gd] (mM)	0.151 ± 0.048	0.252 ± 0.071	0.281 ± 0.070
K_{trans} (min^{-1})	0.033 ± 0.020	0.071 ± 0.043	0.077 ± 0.037
V_e	0.078 ± 0.066	0.095 ± 0.035	0.098 ± 0.038

Results

The mean (± S.D.) relaxation and pharmacokinetic parameters obtained from this series of patients are shown in the adjacent table. For all regions K_{trans} and V_e were positively correlated with Max [Gd] (r^2=0.658, p<0.01 and r^2=0.727, p<0.05 respectively). Further the difference between means for tumour and peripheral zone were significant (p<0.05) for all parameters but most marked for K_{trans}. Unfortunately no significant differences were observed between tumour and BPH. Interestingly, in all cases K_{trans} was greater in tumour than in peripheral zone (chart). This finding suggested that K_{trans} maps could provide an indication of tumour location within the various enhancing tissues of the prostate. In the example shown (figure), the T_2W-image clearly demonstrates a large focus of tumour in the left posterior peripheral zone alongside mixed signal BPH. Although the AUC map shows extensive contrast uptake in this area there is also considerable uptake throughout the gland. The K_{trans} map, however, clearly localises the tumour and reveals some internal heterogeneity.





Discussion

Pharmacokinetic parameter mapping clearly identifies malignant areas in heterogeneously enhancing prostate. The results demonstrate that K_{trans} maps should enable the identification of tumour within heterogeneously enhancing peripheral zone, delineate its proximity to crucial structures and reveal the extent of extra-glandular involvement. They may also prove clinically useful in providing a biopsy target and in revealing intra-tumoural heterogeneity. Comparison with whole mounted prostate specimens is being undertaken to provide the confirmation of this hypothesis.