Functional Imaging of the Prostate: Quantitative DCE-MRI and its Repeatability

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Introduction: The adiabatic approximation to the tissue homogeneity (AATH) model [1] has been used in the analysis of dynamic contrast-enhanced (DCE) MRI data to obtain estimates of flow and microvascular permeability in the prostate [2]. Estimates of extravascular-extracellular volume (v_e) and transit time (T_c) were found to be imprecise in this previous study, and this has been addressed in a new prospective study of patients with benign prostatic hyperplasia (BPH).

Methods: Data were acquired from 12 patients with BPH on a 1.5 T Philips Intera system using a SENSE cardiac coil. T_1 was measured using a 3D inversion-recovery turbo-FLASH (IRTF) sequence with 5 TIs (~4 min acquisition). This method was validated using a Eurospin T_1 phantom, by comparing it with a spin-echo inversion recovery (SEIR) method. DCE-MRI data were acquired using a 3D FLASH sequence (30° flip angle; 40x40x10 cm FOV; 176x176x20 matrix; TR/TE 3.37/0.86 ms). SENSE was used to maximise temporal resolution whilst using an increased TR to boost baseline SNR [3,4]. DCE-MRI data were analysed using the AATH model to give estimates of T_c, v_e, flow F and extraction fraction E. Repeatability was assessed by performing two scans, one week apart, on each patient.

Results: Figure 1 shows phantom T_1 values measured with IRTF and SEIR. The solid line is the line of identity. The log-transformed limits of agreement for the Bland-Altman plot are 0.98 and 1.05. The mean values for the fitted DCE-MRI parameters and T_1 for whole prostate are shown in table 1, with standard deviation and test-retest coefficient of variation (CoV). Figure 2 shows example uptake curves, model fits, AIFs and fitted parameters for both visits of a single patient.

Discussion: The IRTF method for measuring T_1 shows excellent agreement with the gold-standard SEIR. T_1 measurements made in vivo have very good repeatability, and were longer than previously reported [5]. The AATH model is ill-posed and some of the parameters are interdependent, making model fitting challenging. Increasing the length of the dynamic acquisition has led to improvements in estimation of v_e (all estimates were <1) and in this preliminary analysis of the data the test-retest CoVs are comparable with the 15-37% obtained with a simpler model [6]. However, the repeatability of T_c was poor. This may reflect a genuine heterogeneity of T_c within the gland [7] or a particular sensitivity to motion artefact. A combination of image registration with the analysis of homogeneous sub-structures (e.g. segmented glandular or stromal BPH and peripheral zone) may help to reduce this variability. In conclusion, we have developed a quantitative protocol for functional imaging of the prostate that may also have potential applications in other areas of the body.

	E	F_b /ml ml^{-1} min^{-1}	T_c /min	v_e /ml ml^{-1}	T_1 /ms
Visit 1	**0.72 ± 0.11**	**0.19 ± 0.07**	**0.75 ± 0.41**	**0.32 ± 0.11**	**1392 ± 70**
Visit 2	**0.71 ± 0.15**	**0.21 ± 0.09**	**0.71 ± 0.31**	**0.35 ± 0.13**	**1341 ± 105**
Test-retest CoV	**21**	**31**	**57**	**18**	**4.1**

Table 1 – Mean value, SD and test-retest CoV for DCE-MRI parameters, and T_1 for both visits; n = 12.

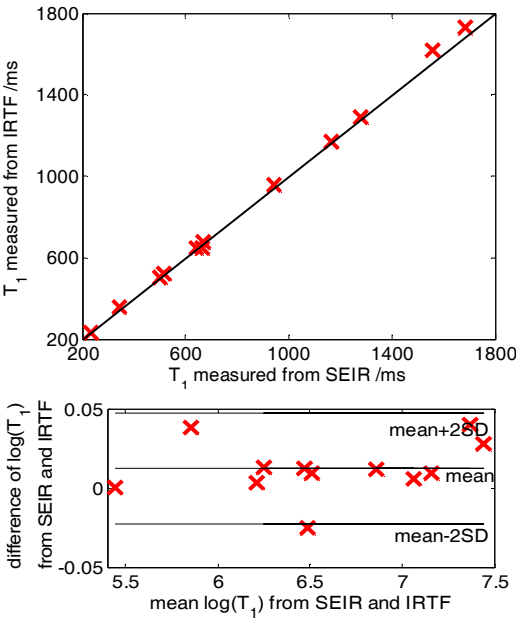

Figure 1 – Scatterplot and Bland-Altman plot for T_1 measured for Eurospin phantom tubes, IRTF vs SEIR method

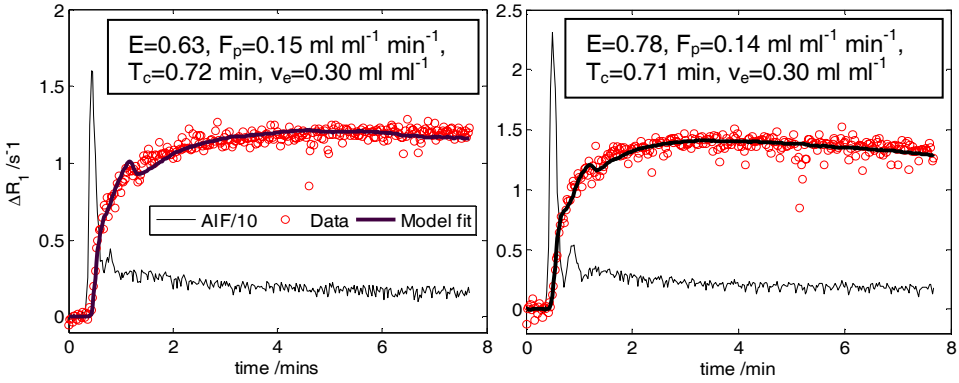

Figure 2 – Uptake curves, model fits and AIFs (divided by 10 for clarity) for the same patient, visits one (L) and two (R)

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References:

[1] St Lawrence *et al JCBFM* 1998;**18**:1365
[2] Kershaw *et al MRM* 2006;**56**:986
[3] Weiger *et al MRM* 2005;**53**:177
[4] Buckley *et al Proc ISMRM* 2005;557
[5] Buckley *et al Radiology* 2004;**233**:709
[6] Roberts *et al JMRI* 2006;**23**:554
[7] Koh *et al Phys Med Biol* 2001;**46**:1519