Diffusion weighted imaging of prostate and rectal wall: comparison of biexponential and monoexponential modelled diffusion coefficients

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Introduction:

Diffusion weighted (DW) MRI is increasingly being used to identify prostate cancer, in particular to delineate tumors within the central gland where T2-W imaging has poor contrast between benign and malignant nodules. Quantitation using Apparent Diffusion Coefficients (ADC) usually entails monoexponential fitting of the DW data and does not account for the contribution from intravoxel incoherent motion (IVIM). Biexponential modelling over a large range of b-values allows the fast IVIM component to be separated from the slower component to reveal the volume fraction (PF) of microvasculature within a voxel and the 'true' molecular diffusion coefficient (D). The purpose of this study was to examine whether biexponentially derived diffusion coefficients (D) from prostate central gland (PCG), prostate peripheral zone (PPZ), and rectal wall (RW) tissues with 11 b values from 0-800s/mm^2 improved modelling of these tissues and whether they were significantly different from monoexponentially derived apparent diffusion coefficients (ADCs).

Methods:

Fifty patients (mean age 66 years, range: 53 to 78 years) were imaged using an endorectal receiver coil on a 1.5T Intera MR scanner (Philips Medical Systems, Best, Netherlands). Following routine T2-weighted imaging, DW images were obtained axially using single shot echo-planar imaging. Twelve 4mm thick slices with TR=2500ms, TE=69ms, FOV=200cm with 96^2 matrix reconstructed to 128^2 were obtained. Diffusion gradients with 11 b values (0, 1, 2, 4, 10, 20, 50, 100, 200, 400, 800 s/mm^2) were applied in the phase encoding direction. In each patient, a region of interest (ROI) was drawn on the DW image (b=0s/mm^2) in a homogenous area of normal tissue in the PCG, PPZ and RW (mean ROI sizes: 175, 82, and 56mm^2 respectively). The data was fitted with the IVIM model to give values for PF and D for each tissue type. A monoexponential function was also fitted to the signal from DW images using 6 b values (20-800 s/mm^2) to give the ADC for comparison.

Fig **1** Mono- and biexponential diffusion coefficients for central gland, peripheral zone and rectal wall tissue.

Results:

For each tissue type (PCG, PPZ and RW), the mean D and ADC values were statistically different (p<0.05, Fig 1). Monoexponential derived ADCs differentiated the three tissue types (p=0.00) and could be fitted for 100% of PCG, and 96% of both PPZ and RW tissues. The IVIM diffusion coefficient D could not distinguish between the three tissues (p>0.05) and the number of cases which could be fitted to the biexponential model was 68% (PCG), 80% (PPZ) and 94% (RW). Chi-squared values showed that the monoexponential model was significantly better at fitting the data for the PCG (p<0.05); however, there was no significant difference between the biexponential and monoexponential models for fitting the data from PPZ and RW tissues. The PF of the PCG was significantly different from the other two tissues (p<0.05, Fig 2).

Discussion:

The monoexponential model was better at describing the data for the PCG, but both models could describe the PPZ and RW tissues equally well. The failure of the biexponential model to fit the PCG data suggests that perfusion effects may be less important here. The biexponential model can be used to describe PPZ and RW data, suggesting there is a fast perfusion component. In these tissues biexponential fitting using D rather than ADC may offer improved differentiation between normal tissue and tumor. For PCG lesions where monoexponential fitting is adequate, fewer b values and thus shorter imaging times may be employed.

Fig 2: Perfusion fractions for the three tissue types; the central gland tissue is distinguishable from the peripheral zone and rectal wall for the 68% of cases successfully modelled.

Conclusions:

An estimate of the D, PF and ADC for the prostate (PCG and PPZ) and rectum (RW) was derived from endorectal single shot echo-planar DW-MRI with 11 b-values ranging from 0 – 800 s/mm^2 using two different models. The biexponential model could not adequately describe the PCG, but could identify a perfusion component in the PPZ and RW tissues, allowing a true diffusion coefficient (D) to be calculated which was statistically different 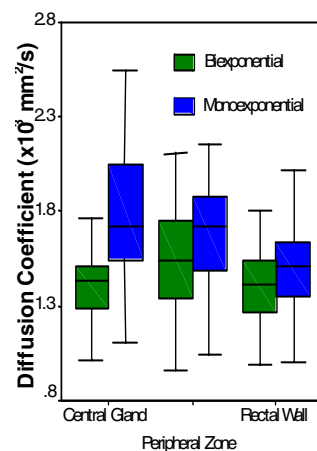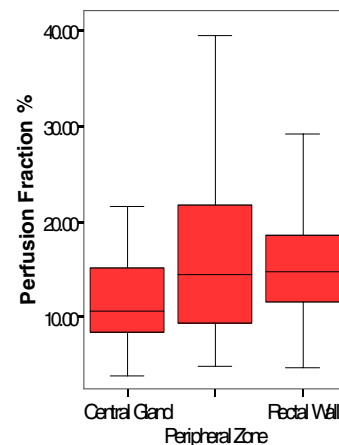from the monoexponentially derived values of ADC.