Effect of external beam radiotherapy on prostate ADC values

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Introduction

The effects of ionising radiation on cells are complex and include cell apoptosis, cell swelling and cell lysis, all of which affect the cellular density. The aim of this study was to investigate if the apparent diffusion coefficient (ADC) changed before and after external beam radiotherapy (EBRT) in response to these effects using similar acquisition techniques to studies that have demonstrated a significant difference in ADC between normal prostatic peripheral zone and prostate cancer (1,2). The effect of using different combinations of b-values to calculate the ADC was also investigated.

Methods.

17 patients who were undergoing radical EBRT (55 Gy in 20 fractions) for localized prostate cancer participated in this study. All patients had been on hormone therapy prior to EBRT commencing. Patients were excluded if they had contraindications to MRI scanning. MRI scans were performed on a 1.5T Siemens Avanto scanner with SQ gradients. All patients had T2W-TSE and diffusion MRI scans of their prostate before the first EBRT fraction and immediately after their last fraction of EBRT. The diffusion MRI scans used a single-shot diffusion weighted echo-planar imaging (DW-EPI) sequence using a 3-scan trace diffusion acquisition with b-values of 0, 50, 300, 500 and 800 s/mm^2. The slice positions of T2W-TSE and DW-EPI scans were matched.

Regions of interest were drawn on the T2W images pre-radiotherapy corresponding to areas of low signal intensity (malignant regions) and areas of hyperintensity (normal peripheral zone). These regions were transferred onto diffusion weighted trace images generated by the scanner. The regions were shifted in the phase encoding direction (anterior-posterior) if the prostate centre of gravity had moved between the T2W and the trace images. Post-radiotherapy images were registered to pre-radiotherapy images using automatic mutual information algorithms and manual registration (Slicer Version 2.6, www.slicer.org). ROIs were transferred onto the registered image dataset. Apparent diffusion coefficients were calculated by fitting the signal intensity data obtained from the trace images to the equation $S=S_0\exp(-b.ADC)$. The ADC values were calculated using the following combinations of b-values: all b values, b=50 and 300 s/mm^2, b=300 and 500 s/mm^2 and b=50, 300 and 500 s/mm^2. This was performed for both malignant and normal ROIs. The paired t-test was used to test the significance of any differences between pre- and post-treatment ADC values. All statistical significances quoted are at the 0.05 level.

Results

Two patients were excluded from the analysis due to technical problems. In 14 patients normal peripheral zone was identified whereas malignant tissue was identified in all 15 patients. The ADC values, calculated using b-values of 50 and 300 s/mm^2, pre- and post-treatment are shown in the figure for malignant and normal regions.

Malignant ROIs - b50 and b300

b values (s/mm^2)	Malig Pre	Malig Post	Normal Pre	Normal Post
All	0.917	0.804	1.282	0.992
50,300	1.182	1.043	1.608	1.321
50,300,500	1.066	0.927	1.502	1.157
300,500	0.909	0.770	1.358	0.937

Table 1: Average ADC values (x10^{-3} mm^{2}s^{-1})

The calculated average ADC values are shown in table 1. All combinations of b-values showed a significant drop in ADC pre and post treatment except for b=300 s/mm^2 and 500 s/mm^2 for malignant tissue. The signal intensity of the b=0 trace image was significantly higher pre radiotherapy than post radiotherapy for both normal (120 vs 81 respectively, p=0.0008) and malignant tissue (79 vs 70 respectively, p=0.03).

Normal ROIs - b50 and b300

Discussion

The calculated ADC had a strong dependence on the choice of b-values. The highest average ADC values were obtained when the b=50 s/mm^2 and b=300 s/mm^2 combination was chosen. The lowest average ADC values were obtained when the b=300 s/mm^2 and b=500 s/mm^2 combination was chosen.

The results indicate the influence of two effects; (i) that if low b-values (<150) are included in the analysis then perfusion effects can lead to an increase in the calculated ADC and (ii) if high b-values are used which have insufficient SNR then this can lead to a decrease in the calculated ADC unless explicitly accounted for. In this study it was observed that the trace images with b=800 s/mm^2 had insufficient SNR and that this was also sometimes true of the b=500 s/mm^2 images. Therefore, the b-vaues chosen to calculate the effect of radiotherapy were b=50 and b=300 s/mm^2. This was considered to provide the most noise resistant calculation although there may still be some perfusion contribution to the final ADC value. Most combinations of b-values showed that the ADC reduced post treatment compared to pre treatment values. This may be a consequence of radiotherapy cellular changes e.g. cell swelling.

References

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