Comparison of prostate tumor volume delineation between multi-parametric MRI sequences when planning for hypofractionated radiotherapy

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Target Audience: Radiologists, Radiation Oncologists and Physicists involved in prostate MR and radiotherapy planning.
Purpose: Accurate delineation of prostate tumor outlines with small margins is essential for hypofractionated radiotherapy. Too large a tumor volume measurement increases the risk of complications, and too small a measurement reduces the chance of effective treatment[1]. An intraprostatic margin around the gross tumor volume (GTV) of at least 2mm is calculated prior to radiotherapy to allow for intrafraction motion [2]. Regions-of-interest (ROIs) are currently drawn on T2W sequences to outline prostatic zonal anatomy and tumor regions. However, the differences in tumor volume derived from Diffusion Weighted Imaging (DWI) and Dynamic Contrast Enhancement (DCE) images over T2W images have not been documented. This study was designed to determine differences in manual measurement of GTV on multi-parametric (mp)MR sequences (T2W, DWI and DCE) in order to establish which sequence is preferred when planning radiation dose boosting.
Methods: Eligible patients were invited to participate in a Phase II clinical trial, DELINEATE, which delivers a radiation dose boost to an MRI-identified intraprostatic tumor nodule. mpMRI was performed in 20 patients with written informed consent using an endorectal coil at 3T (Achieva, Philips, Best, The Netherlands). T2W, DWI (b=0, 100, 300, 500, 800 mm^2/s) and e-THRIVE DCE (temporal resolution 12 sec) data were acquired. ROIs were manually defined slice-by-slice on an extended MR workstation (Philips) by a radiologist with 3 years prostate mpMRI experience. T2W (TR 2627ms, TE 110ms), ADC maps calculated using a mono-exponential fit of all b-values, and DCE at peak enhancement (range 58.5-62.5sec) sequences were used to define ROIs on anonymized images. The radiologist was blinded to the clinical and pathological findings. No comparison was made between sequences to assess for tumor size or location, and a time period of one week was maintained between assessments of each sequence to minimise possible memorisation of tumor locations. GTVs were calculated per patient in cm^3 accounting for sequence slice thickness (T2W 2.2mm interval 0.1mm, ADC 2.2mm interval 0.1mm, DCE interpolated 2.3mm).

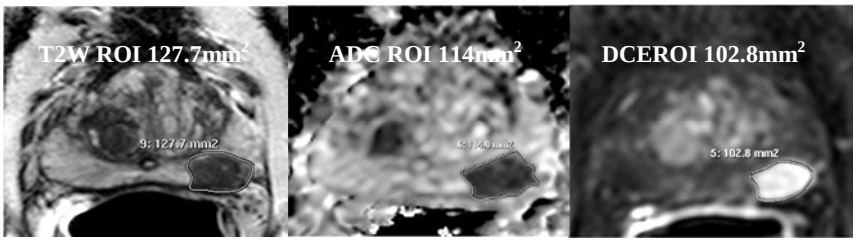

Fig 1: Axial T2W, ADC map and e-THRIVE DCE location-matched slices showing ROI measurements

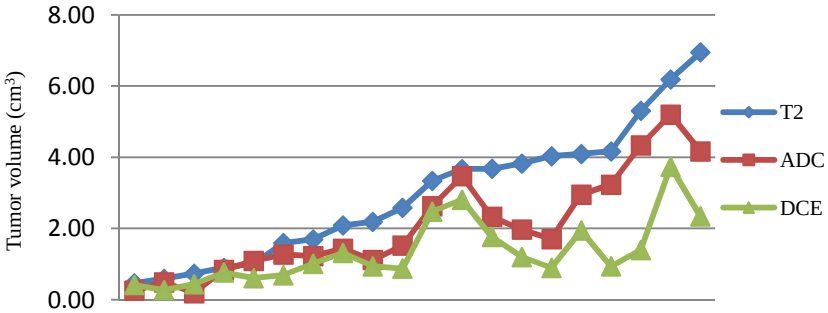

Fig 2: Cases in order of ascending tumor volume as measured on T2W sequences

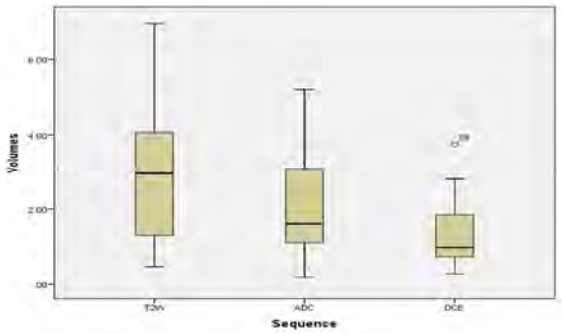

Fig 2: Box plot of GTVs for each mpMRI sequence

Results: There was a statistically significant difference in GTV measurements between imaging sequences as determined by one-way ANOVA [F (2,57) = 6.095, p =0.004]. Post hoc comparisons using the Tukey HSD test indicated that DCE GTVs (1.3±0.91) were significantly smaller than T2W GTVs (2.95±1.88). There was no significant difference between T2W and ADC GTVs (p=0.144) or ADC and DCE GTVs (p=0.265). There was a mean difference of 30% between T2W and ADC which was not statistically significant, and a significant 48.7% mean difference between T2W and DCE. For tumors less than $1cm^3$ there was little difference between GTV measurements, but the differences between GTVs on the 3 sequences increased with tumor size.
Discussion: The lack of variability in GTV for small tumors indicates that the discrepancies between sequences for larger tumors is unlikely to represent measurement error, but is sequence dependent. T2W and ADC map derived GTVs were not significantly different, but tended towards 30% smaller ADC GTVs. GTVs from DCE sequences correlate best with histological tumor volumes and have the highest sensitivity for detecting tumor4 and consistently provided the smallest GTV measurement, indicating a smaller area of abnormal perfusion than the corresponding T2W abnormality. This study is limited by not having histopathological measurements for comparison, and only one radiological observer.
Conclusion: T2W sequences provide the largest GTV measurement when planning for radiation boost therapy and DCE GTVs are significantly smaller than those on T2W, suggesting T2W are the most useful in the context of radiation therapy planning.

References

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