Planning a boosted radiotherapy dose to the dominant intraprostatic tumour lesion within the prostate as defined by multifunctional MR parameters

Sophie F Riches[1], Geoffrey S Payne[1], Nandita M deSouza[1], Scott Morgan[2], David Dearnaley[3], Veronica Morgan[1], Sharon Giles[1], and Mike Partridge[4]

[1]CR-UK and EPSRC Cancer Imaging Centre, Institute of Cancer Research and Royal Marsden NHS Foundation Trust, Sutton, Surrey, United Kingdom, [2]Division of Radiation Oncology, University of Ottawa, Ottawa, Ontario, Canada, [3]Division of Radiotherapy & Imaging, Institute of Cancer Research and Royal Marsden NHS Foundation Trust, Sutton, Surrey, United Kingdom, [4]Gray Institute for Radiation Oncology and Biology,Department of Oncology, University of Oxford, Oxford, Oxfordshire, United Kingdom

Target Audience Clinicians and physicists investigating prostate cancer and MRI for radiotherapy planning

Purpose To investigate the feasibility, advantages and limitations of using a boosted radiotherapy dose to the dominant intraprostatic tumour lesion within the prostate as defined by multifunctional MR parameters by comparing the therapeutic ratio of a 84 Gy boosted IMRT radiotherapy plan with a conventional clinical treatment dose of 72 Gy delivered uniformly to the prostate.

Methods In 23 patients due for radiation therapy to the prostate, diffusion-weighted imaging (DWI), dynamic contrast-enhanced imaging (DCE-MRI), T_2-maps and 3D proton MR spectroscopic imaging (MRSI) were acquired and parametric maps were calculated. The location of the dominant intraprostatic lesion was predicted using a combined parameter model previously validated in 24 patients undergoing prostatectomy (abstract submitted). Functional MR images acquired with an endorectal coil were registered with anatomical images acquired without the coil in place using non-linear point-based registration to replicate positioning during radiotherapy delivery. Immediately following the scan, patients started a three month course of neo-adjuvant hormone-downregulation therapy, at the end of which a further anatomical non-endorectal image was obtained. A bi-linear scaling algorithm was applied to account for the non-linear shrinkage of the prostate during the hormone therapy, allowing an outline of the dominant intraprostatic lesion determined on the pre-treatment images to be translated onto the post-hormone treatment images, on which the tumour was no longer identifiable [1-3]. Rigid body registration with radiotherapy planning CT using implanted gold-seed fiducials allowed IMRT planning of a lesion dose of 84 Gy with a dose of 72 Gy to the rest of the prostate. Dose-volume histograms (DVH) for prostate, bladder and rectum were constructed and the tumour control probability (TCP) and normal tissue complication probabilities (NTCP) were calculated. These were compared with the conventional uniform 72 Gy prostate dose plan to see if improved tumour control was achievable without compromising normal tissues.

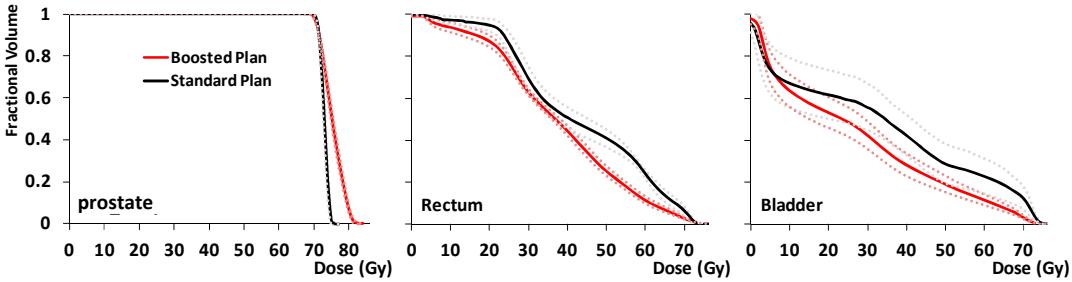

Fig 1. DVHs for prostate (left), rectum (centre) and bladder (right) for standard clinical plans (black) and a boosted dose plan (red) using an MR-defined tumour target, (dashed lines indicate 95% confidence limits).

Results Clinically deliverable IMRT plans were possible in the 20/23 patients with identifiable dominant lesions. Mandatory constraints were met for both radiotherapy plans in all patients, but only 75% of boosted plans met optional constraints in comparison with 100% of conventional plans. The DVHs for the prostate, rectum and bladder are shown in Fig 1. Paired t-tests show that there was a significant increase in the area under the DVH of the prostate (75.1 ± 0.6 vs. 72.7 ± 0.3 Gy, $p<0.001$) and unexpectedly significant decreases in the areas under the curve for the rectum (38.2 ± 2.5 vs. 43.5 ± 2.5 Gy, $p<0.001$) and bladder (29.1 ± 9.0 vs. 36.9 ± 9.3, $p<0.001$). The TCP for the prostate was significantly increased (80.1 ± 1.3 vs. 75.3 ± 0.9 Gy, paired t-test, $p<0.001$) and the rectal NTCP significantly lowered (3.84 ± 3.65 vs. 9.70 ± 5.68 Gy, $p=0.04$) in the boosted plan compared with the standard clinical plan. The NTCP for bladder was zero for both plans.

Discussion Dominant intra-prostatic lesions were identified in 20/23 patients using a multifunctional MR model and it was possible to register these functional images to radiotherapy planning CT using interim anatomical non-endorectal images acquired prior to and post hormone therapy. It was possible to plan delivery of a focal boost in all patients who had a dominant lesion whilst maintaining current dose levels to surrounding normal structures. Tumour control and normal tissue complication modelling revealed that, as well as achieving significantly higher tumour control, the boosted plans were also significantly less toxic to the bladder and rectum; possibly due to relaxation of the requirement for uniform dose to the entire prostate in the optimisation algorithm.

Conclusion It has been shown that it is possible to use MR to define a region of tumour within the prostate and deliver a focal boost resulting in a greater therapeutic ratio for patients, with potentially greater tumour control and fewer side-effects from the treatment.

References [1] Riches, SF *et al*, *Diffusion* Proc ISMRM, 2007 #793. [2] Mueller-Lisse, UG., *et al*., Magn Reson Med, 2001. **46**(1): p49-57. [3] Padhani, A. R., *et al*., **218**(2): p365-74.