Analysing the feasibility of adapted MR-guided SABR for prostate cancer patients with hip prosthesis

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Introduction

With an aging population, the increased incidence of osteoporosis and hip replacements is evident[1]. Metal hip prosthesis in CT-based planning images and CT-guided radiotherapy treatment produces significant image artefact, limiting the accurate delineation of target volumes and organs at risk (OARs).

Challenges in clinical target volume (CTV) definition and image-guided radiotherapy (IGRT) presents limitations in dose calculation, analysis of scatter and reduced beams entering through the prosthesis when planning. Such limitations increase the difficulty of prostate SABR planning, for example, an increased Monitor Unit (MU) contribution anteriorly and posteriorly can lead to poor control of the prescription dose, with OAR constraints becoming harder to achieve. The complexity of delivering CT-based ultra-fractionated prostate radiotherapy often requires interventions such as rectal spacers, implanted fiducial markers, diagnostic MRI images for planning and for patient groups with bilateral hip prostheses SABR treatment may often be infeasible without an MRI scan[2, 3].

0.35T MR images acquired for planning as part of the daily adaptive workflow in MR-guided radiotherapy (MRgRT) enhances CTV and OAR visualisation, image matching and real-time target tracking during treatment. The feasibility of MRgRT is highlighted through this improved anatomical visualisation and delineation subsequently allowing reduced dose to the OARs, minimising side effects and the need for supplementary invasive procedures.

Method

We have planned 212 patients of MRgRT prostate cancer (Pca), and retrospectively identified 16 patients with metal hip prosthesis who were referred for MrgRT SABR over the last 3 years.

MR images for target and OAR delineation were acquired on a ViewRay MRIdian which features a 0.35 T magnet. Additionally, a CT scan in the treatment position was acquired for electron density data. Patients were required to have 200mLs of water and empty their bowels 20 minutes prior to their treatment appointment. The OARs contoured included femoral heads, bladder and rectum.

Artefact produced by the prosthesis on the CT scan were identified and density overridden along with the subsequent missing CT data. Overrides were defined as bone, air, tissue and prosthesis (avoidance structure). The CTV had a margin expansion in all directions by 3mm to create a planning target volume (PTV). IMRT plans were optimised using 6 MV photon beams on the Viewray MRIdian TPS with around 60 segments distributed over 19 beams positioned to avoid the high-density prosthesis.

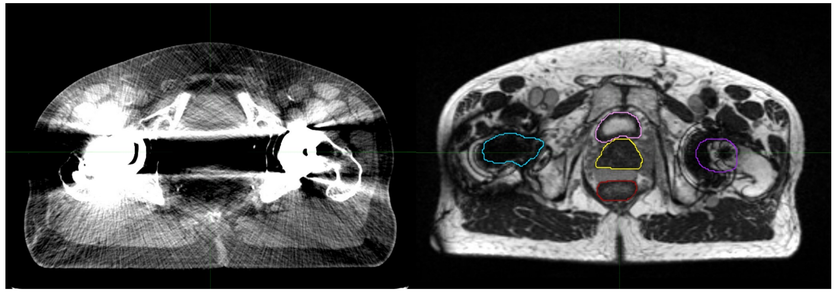

Figure 1. Axial section of prostate and seminal vesicles in patient with bilateral hip prosthesis on planning CT (left) and MR Linac (right)

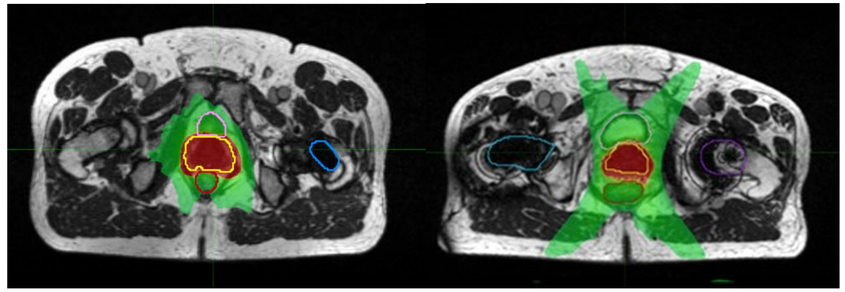

Figure 2. Baseline plan in patient with UHP (left) and BHP (right). PTV, rectum, bladder, and hips shown with 100%, 95% and 50% isodoses.

Dosimetric plan quality was compared between patients with and without hip prosthesis. Key metric included: volume of the PTV receiving the 100% and 95% of the prescription dose (PTV: V(100%), V(95%)) and prescription dose spillage (PDS).

Results

Patients were treated with daily adaptive MRgRT to their prostate ± seminal vesicles with doses of 36.25 in 5# with an optional 40 Gy boost to the prostate and proximal 1 cm of seminal vesicles for high-risk patients. The prostate volumes for the patients with metal hip prosthesis was 40.97-118.24 cc.

Baseline dosimetry for these plans were comparable whilst meeting OAR dose constraints and achieving optimal PTV coverage[2]. There was no statistically significant difference in PTV V(95%) or PDS between patients with or without hip prothesis ($p < 0.05$ for both).

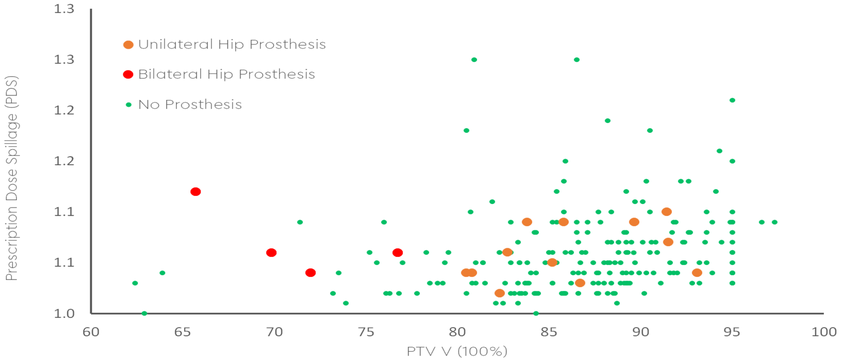

Figure 3. Patients with hip prosthesis did not receive inferior treatment plans compared to patients without hip prosthesis.

Patient reported acute treatment related toxicities and PSA levels for UHP/BHP patients compared to the control group post follow up period (2-12 months) were clinically acceptable and minimal[4]. Factors other than prescription dose that may impact on the incidence of these toxicities such as pre-existing co-morbidities were not analysed. Treatment accuracy was confirmed by reviewing the impact of metal hip prosthesis on image spatial integrity measured with a 2D distortion phantom. Previous papers state protheses are not causable for quantifiable MR distortion[5].

Conclusion

Adaptive prostate MRgRT SABR allows for feasible treatment delivery in patients with metal hip prosthesis. The considerable metal artefact reduction shown permits better visualisation and target/OARs delineation. Therefore, demonstrating an increased accuracy and efficacy in planning and treatment whilst minimising dose to OARs. A further review, involving a greater number of patients will establish the impact of hip prosthesis on MRgRT prostate SABR plan quality.

Confidence in delivering MRgRT SABR for this group enables us to provide quality treatment outcomes for this aging population. With the credible evidence for prostate cancer SABR, MRgRT offers a crucial treatment option for this patient group with increased hip replacements and osteoarthritis.

References

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