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EASTERN TIME [GMT-4]

Dosimetric Robustness Analysis of Iodinated Rectal SpaceOARVue Hydrogel using RayStation's Dose Deformation Toolbox

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PURPOSE/OBJECTIVES

- Rectal spacer hydrogels are used in prostate cancer patients to create space between the prostate and the rectum (1).
- Hydrogels are typically water-equivalent, requiring an MRI for delineation. Iodinated hydrogels (SpaceOAR Vue, Augmenix, Inc.) are being commercialized to allow visualization on CT alone. This was particularly helpful during the COVID-19 pandemic to minimize the time and points of contact for patients in the hospital.
- A potential concern is the effect of the denser hydrogel on the robustness of the modulated treatment plan. Small changes in patient set-up or organ motion could cause significant dosimetric changes due to a larger amount of MUs delivered through denser materials overlapping with the target. This is a known issue for hip prostheses (2).

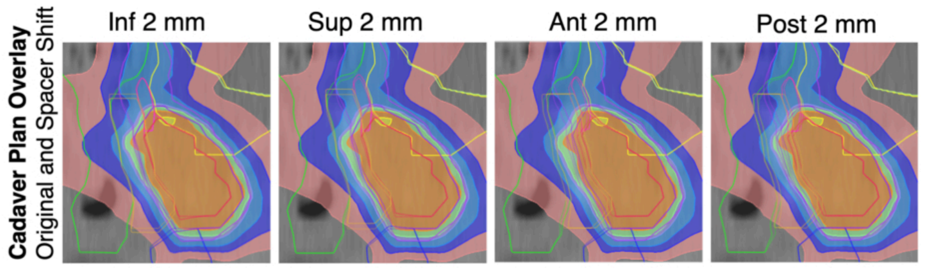
Goal of this Work

➢**To simulate and investigate the dosimetric effects of density variations, setup errors, and spacer shifts for patients with iodinated spacers compared to water-equivalent spacers.**

METHOD

A clinically deployed RayStation 8A planning system was used to create a standard-of-care prostate VMAT plan for patients with an implanted hydrogel spacer. All plans were 6MV single arc VMAT with two dose levels: a standard dose to a prostate and seminal vesicles (SVs) PTV and a boost dose to a prostate PTV. The PTV expansion was 5 mm in all directions, except 4 mm in the posterior direction. The fractionation was either a simultaneous integrated boost (SIB) of 28 fractions of 180 cGy to the prostate+SVs and 250 cGy to the prostate (n=5), or a sequential boost of 28 fractions of 180 cGy to the prostate+SVs and 16 fractions of 180 cGy to the prostate (n=2). Patients were included on an IRB-approved dosimetric study protocol.

RayStation's built-in dose deformation tools (3), which are based upon a biomechanical finite element method (Morfeus algorithm) (4,5), were used to simulate setup errors of 5mm, spacer shifts of 2mm, and changes in spacer density. The resulting changes in average dose and D1 were analyzed for all targets and OARs. The simulated setup error and spacer shift were repeated for n=4 clinical patients with water-equivalent spacers and the first n=2 clinical patients with iodinated spacers plus a cadaver scan supplied by Augmenix, Inc (n_{tot}=3 with iodinated spacers).

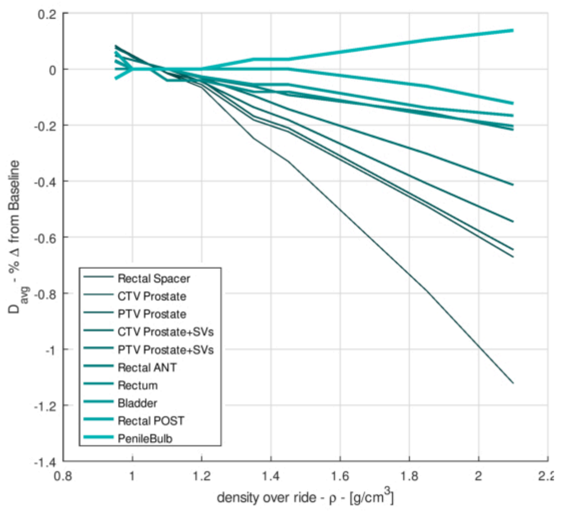


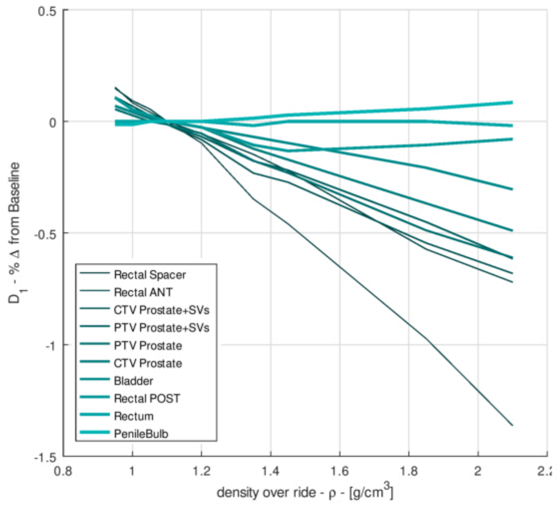
Above: Zoomed in overlay of the original and deformed Sagittal view of the target, spacer, and rectum, after a spacer of 2 mm in the inferior, superior, anterior, and posterior directions. White arrows indicate simulated spacer shift.

RESULTS I

Relationship between spacer density and the change Davg/D1 for each OAR/target in this subject (legend ordered max Δ)

The target & OAR dosimetry was evaluated as a function of spacer density, which was overridden in RayStation for the cadaver subject. **With a simulated doubling of iodinated HU in the cadaver, D1 and Davg changed by <1.5% across all targets and OARs.** Uncertainties in spacer density may be present as the gel is injectable and can coalesce creating especially dense inhomogeneities; the gel is also broken down and absorbed by the body so there is concern the density may change over the course of treatment.



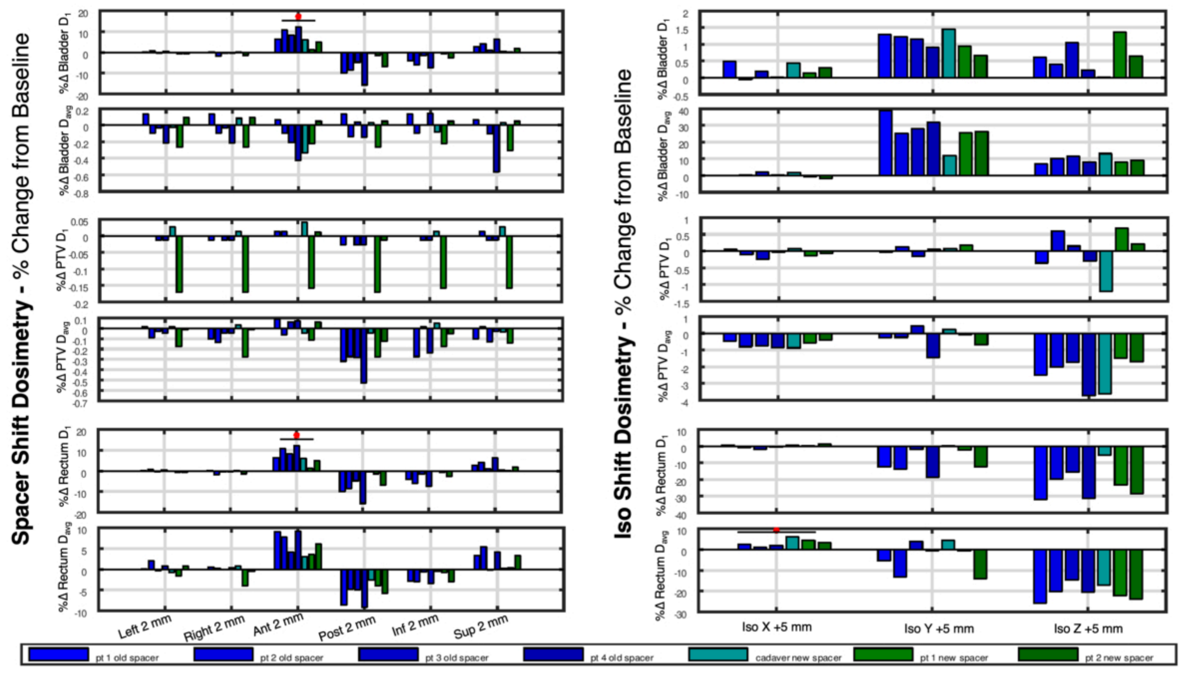


Above: The % change in the Davg (Top) and D1 (Bottom) for each target and OAR as a function of the over ridden density of the hydrogel in the cadaver.

RESULTS II &III

For both hydrogels, dosimetric changes of >20% were observed for some OARs after simulated 5mm set-up errors, but PTV D1 and Davg exhibited less than a 5% change. For 2mm spacer-shifts, all OAR/target dosimetric changes were <5% except for the rectum. For both setup and spacer-shift analyses, all dosimetric changes were insignificant between water-equivalent and iodinated spacers (p>0.01).

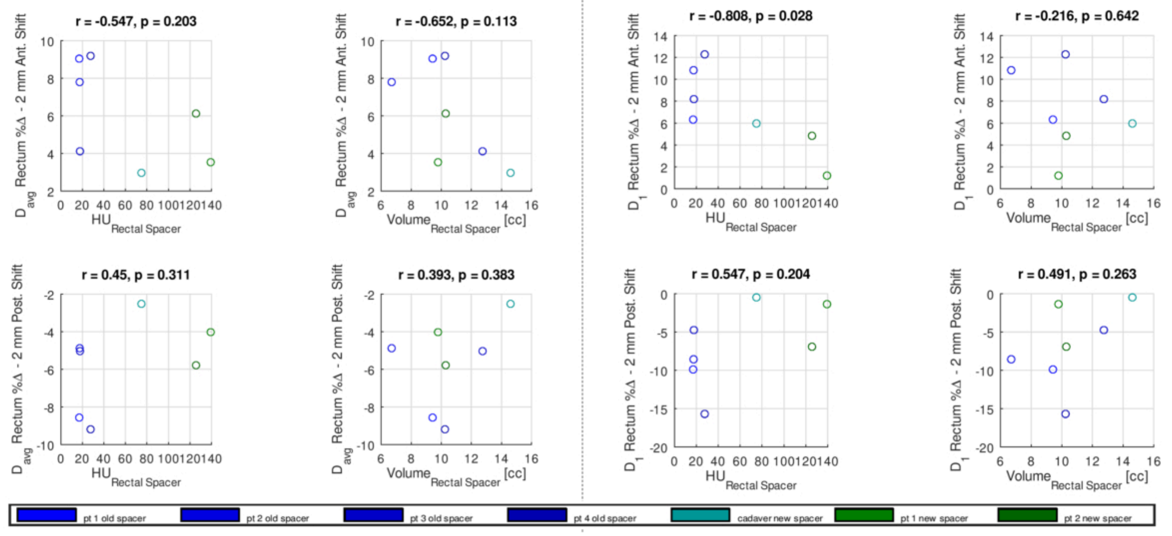
The % change in the D_{avg} & D_1 for the Rectum, PTV (Prostate & SVs), and bladder in each subject after either a simulated spacer shift of 2 mm (left) or a set-up error of 5 mm in each axis direction (right)



Above: The % change in the D1 and Davg from baseline for the Rectum, PTV (prostate & SVs), and Bladder are displayed for all 7 subjects. Red asterisks indicate a p-value between 0.01 and 0.05 for an unpaired t-test between the water equivalent spacers (blue) and iodinated high-Z spacers (teal & green).

Correlations between rectum D1 and Davg changes after an Ant or Post spacer shift and either spacer volume or average HU were all statistically insignificant, except for a significant inverse relationship (r = -0.808, p<0.03) between spacer HU and the rectum D1 change after an anterior spacer shift. While this would suggest that a spacer with a higher HU results in a lesser risk of a hotspot in event of a spacer shifting anteriorly, more patients would be needed to substantiate this hypothesis.

Correlations between rectum D_1 and D_{avg} change after an Ant or Post spacer shift with either spacer volume or average HU



Above: Scatter plots of the volume or average HU of each rectal spacer and rectum Davg (Left) or D1 (Right) % change after an Ant or Post 2 mm spacer shift. Water-equivalent hydrogels shown as blue and iodinated hydrogels shown as teal & green.

CONCLUSIONS/FUTURE DIRECTIONS

This work has provided initial evidence showing iodinated spacer hydrogels provide significant increase in CT contrast to aid in spacer delineation while causing minimal dosimetric changes compared to water-equivalent hydrogels.

- Iodinated spacer hydrogels had a significantly higher average HU value on the planning CT compared to water-equivalent hydrogels (<HUavg> 113 for 3 patients vs 20 for 4 patients, p < 0.003)
- Dosimetric changes for all targets and OARS were statistically insignificantly different (p > 0.01) for robustness studies with iodinated hydrogels and water-equivalent hydrogels (with an n of 7 patients)
- MRI was not needed to delineate the iodinated hydrogel in the planning CT for this study, and delineating on CT alone became our standard clinical workflow during the COVID-19 pandemic. Studies of spacer motion and changes during treatment as seen on daily CBCT are ongoing.

REFERENCES

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