Pushing the Limits: Proton Spot Deletion in Prostate Nodal Planning

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INTRODUCTION

Spot delete is a technique that can be used in proton therapy planning to reduce dose to normal tissues, but the extent of how many spots can be removed, without compromising plan quality, remains debatable. The impact of spot removal on target coverage, robustness, and biological doses is not fully understood, making it difficult to establish consistent spot delete practices. This study evaluates the planning limits of removing spots at varying distances from prostate nodal cases.

METHODS

Ten prostate nodal cases were retrospectively optimized and evaluated using RayStation v23B. Each included varying prescriptions but similarly drawn prostate, seminal vesicles, and pelvic lymph node target volumes. All plans were generated using two laterals and one PA beam. Robust optimization was performed using 3 mm setup and 3.5 % range uncertainty. All plans were then optimized to the departmental standard of practice (SOP), which includes deletion of all proton spots located within the rectum. Each plan was then duplicated to generate additional planning scenarios with progressive spot deletion thresholds of greater than 2.0 cm, 1.5 cm, and 1.0 cm from all target volumes using an in-house spot delete tool[1]. Plans were optimized to meet institutional clinical planning standards. Nominal dose distributions were evaluated relative to the SOP baseline, followed by robustness analysis. Thresholded to the 80% isodose line, LET evaluation was subsequently performed to assess relative changes associated with increasing degrees of spot deletion.

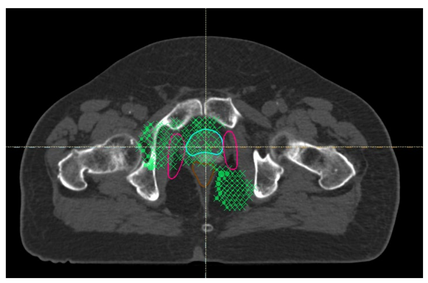

Figure 1: Spots placed minus rectal spots

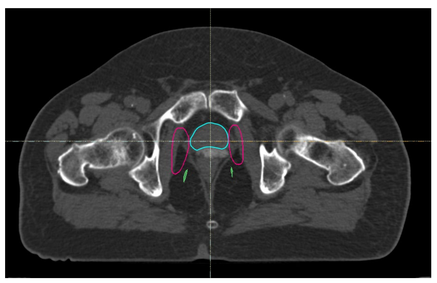

Figure 1a: LET > 4keV/µm (green) on figure 1

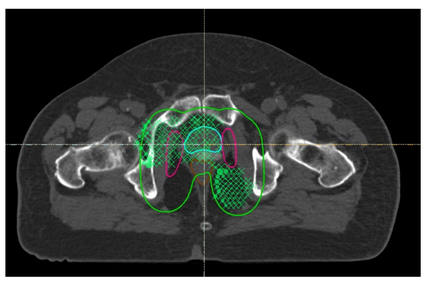

Figure 2: Spots >2cm from targets

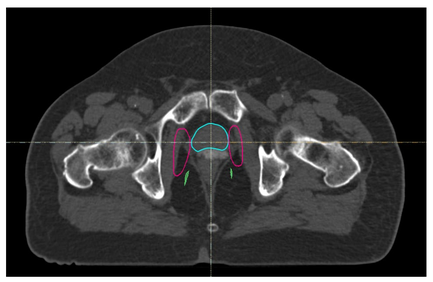

Figure 2a: LET > 4keV/µm (green) on figure 2

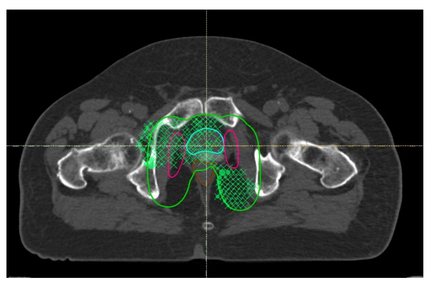

Figure 3: Spots > 1.5cm from targets

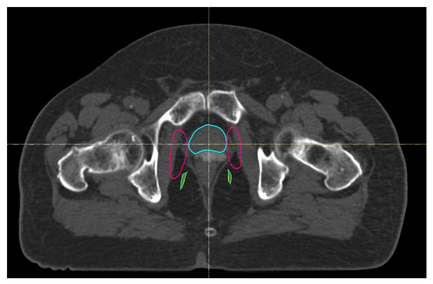

Figure 3a: LET > 4keV/µm (green) on figure 3

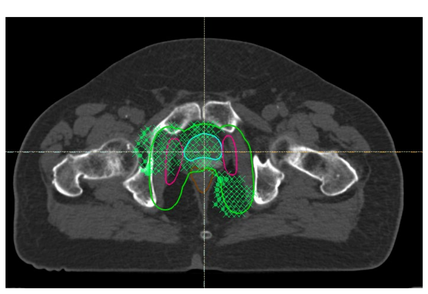

Figure 4: Spots > 1.0cm from targets

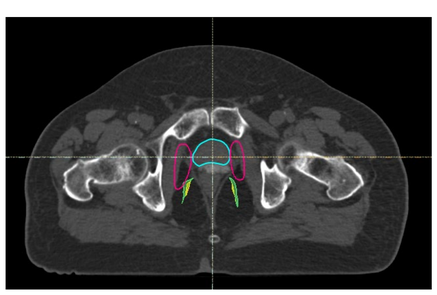

Figure 4a: LET > 4keV/µm (green) on figure 4

RESULTS

- Nominal target coverage was mostly maintained across all spot delete strategies.
- SOP and > 2.0 cm plans showed minimal changes in target or OAR dose.
- > 1.5 cm and > 1.0 cm deletion plans exhibited lower OAR doses but increased plan heterogeneity.
- Robustness (±3mm, ±3.5%, ±3deg rotations) was acceptable for SOP and > 2.0 cm plans but degraded at > 1.5 cm and > 1.0 cm.
- Increased spot deletion was associated with localized LET > 4 keV / µm near the bladder and rectum.

Spot Deletion Threshold	Avg. Spots Deleted	Avg. % Spots Deleted	Dosimetric Impact	Observed LET Impact	Plan Viability
Deleted from Rectum	≈ 200	≈ 1%	No Impact	No Impact	Preferred
> 2.0 cm from Targets	≈ 580	≈ 3%	Mostly identical target and OAR doses	Minimal LET change	Acceptable
> 1.5 cm from Targets	≈ 1,100	≈ 6%	Slightly hotter nominal plans; emerging OAR differences	Mild localized LET increases	Near Borderline Unacceptable
> 1.0 cm from Targets	≈ 3,200	≈ 17–20%	Increased nominal plan heterogeneity; OAR dose much lower	Notable localized LET elevations	Unacceptable

Table 1: Analysis and comparison of all 10 finalized cases

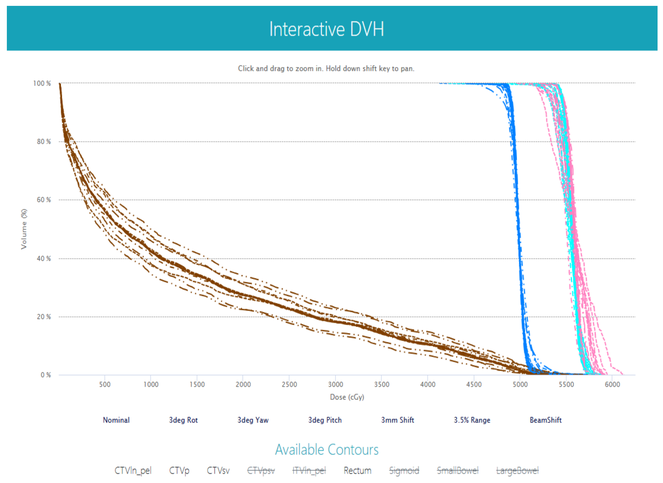

Table 2: Interactive DVH evaluating various robust perturbations. Targets (Prostate – light blue, seminal vesicles – pink, lymph nodes – dark blue) and Rectum - brown visualized

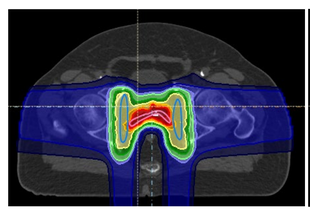

Figure 5: Nominal dose plan with spots deleted > 1cm

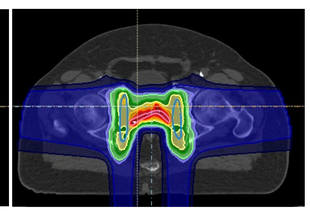

Figure 6: Evaluation of +3.5% range uncertainty

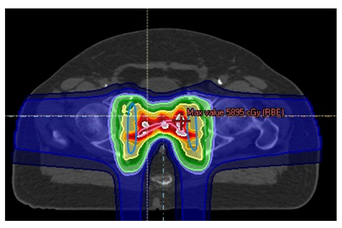

Figure 7: Evaluation of -3.5% range uncertainty

CONCLUSIONS

Progressive spot deletion does impact plan heterogeneity and robustness. While deletion beyond 2.0 cm maintained overall plan quality with minimal observed LET change, additional deletion at 1.5 and 1.0 cm approached the borderline of clinical acceptability due to reduced robustness and localized higher LET near critical structures.

REFERENCES

1. Hedrick SG, Walker B, Morris B, Petro S, Blakey M. Scripted spot removal in PBS proton therapy planning. J Appl Clin Med Phys. 2022

CONTACT INFORMATION

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