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Abstract Title: Dosimetric Assessment of Bony Anatomy Position Variation in Prostate Stereotactic Body Proton Therapy (SBPT)

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Background / Aims:

In prostate proton therapy (PT) utilizing a lateral opposing beam arrangement, a significant portion of proton beam passes through bony anatomy, such as femoral heads and pelvic bone. While target localization is based on fiducial markers matching, positional variation of prostate alters its spatial relationship with the surrounding bony anatomy. Current study simulated such positional changes between the bony anatomy and the prostate and assessed the dosimetric impact in prostate SBPT.

Subjects and Methods:

Six patients with localized prostate cancer that underwent 5-fraction SBPT were included. Treatment plans were optimized for 3mm patient positional uncertainty and ±3% range uncertainty (RU) using RayStation2024A TPS. To simulate the relative positional change between the bony anatomy and the prostate, a translational shift in each direction (right, left, inferior, superior, posterior or anterior) was applied to treatment plan iso-centre, contour of targets (CTV: prostate gland and GTV: intraprostatic lesion), and nearby soft tissues organs-at-risk (urethra, bladder, rectum and penile bulb), whereas the contour of body and bony structures (pelvic bone and femoral heads) remained unchanged. Six scenarios were assessed: 1-3) 5mm shift with and without ±3% RU, 4-6) 10mm shift with and without ±3% RU. Dosimetric evaluations were based upon clinical goals, with the occurrence of failed scenarios reported.

Result:

Table1 summarizes the scenario passing rate and mean clinical goal for failed scenarios of targets and OARs. The relative change in bony structure position slightly reduced target coverage as suggested by D95% and Dmin of CTV and GTV. However, the average D95% of CTV remained above 97% of prescription dose except 10mm shift with -3% RU. Apparently, bony structure position variations did not induce hot spots (D1cc or V105%) in target for most of the scenarios. Apart from D2%≤28.5Gy in penile bulb and Dmax≤30Gy in femoral heads, surrounding OARs (rectum and bladder) passed all clinical goals for all scenarios suggesting that dose spill over was minimal. For urethra inside the target, D0.5cc was occasionally larger than 40Gy. Figure1 shows that failed scenarios occur more frequently along LR direction. Plan iso-center shift along beam path has minimal effect on changing the dose distribution to match the target shift relative to bone and body.

Conclusion:

Dosimetric impact upon relative positional change between bony structure and prostate (up to 10mm) in prostate SBPT is minimal, demonstrating robustness in target coverage and OAR sparing across evaluated scenarios.

		5mm Shift		5mm Shift, +3% Range Uncertainty		5mm Shift, -3% Range Uncertainty		10mm Shift		10mm Shift, +3% Range Uncertainty		10mm Shift, -3% Range Uncertainty	
	Clinical Goals	Passing Rate	Mean Metric (Failed Scenario)	Passing Rate	Mean Metric (Failed Scenario)	Passing Rate	Mean Metric (Failed Scenario)	Passing Rate	Mean Metric (Failed Scenario)	Passing Rate	Mean Metric (Failed Scenario)	Passing Rate	Mean Metric (Failed Scenario)
CTV Prostate	D95.0% ≥ 38Gy (100%)	94.4%	37.8Gy (99.5%)	80.6%	37.7Gy (99.3%)	94.4%	37.6Gy (98.8%)	66.7%	36.9Gy (97.1%)	61.1%	34.4Gy (90.5%)	50.0%	37.3Gy (98.0%)
	Dmin > 36.1Gy (95%)	83.3%	35.3Gy (93.0%)	50.0%	33.4Gy (88.0%)	100.0%	-	66.7%	31.6Gy (83.1%)	25.0%	30.0Gy (78.9%)	63.9%	35.2Gy (92.7%)
	D1.0cc ≤ 39.9Gy (105%)	100.0%	-	97.2%	40.0Gy (100.2%)	100.0%	-	100.0%	-	94.4%	40.0Gy (100.3%)	100.0%	-
	V105% ≤ 1.8cc	100.0%	-	97.2%	1.7cc	100.0%	-	100.0%	-	94.4%	2.7cc	100.0%	-
GTV Prostate	D95.0% ≥ 42.5Gy (100%)	90.0%	42.2Gy (99.2%)	70.0%	41.5Gy (97.7%)	33.3%	41.5Gy(97.7%)	56.7%	40.2Gy (94.6%)	63.3%	39.3Gy (92.4%)	13.3%	40.3Gy(94.9%)
	Dmin > 40.375Gy (95%)	100.0%	-	93.3%	39.6Gy (93.1%)	100.0%	-	80.0%	38.6Gy (90.8%)	73.3%	32.7Gy (76.9%)	66.7%	39.7Gy(93.5%)
Rectum	V42.0Gy ≤ 0.04cc	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
	V40.0Gy ≤ 0.5cc	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
	V36.0Gy ≤ 2.0cc	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
	V36.0Gy ≤ 5.0%	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
	V32.0Gy ≤ 20.0%	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
	V20.0Gy ≤ 50.0%	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
Bladder	V42.0Gy ≤ 0.04cc	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
	V40.0Gy ≤ 2.0cc	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
	V37.0Gy ≤ 10.0cc	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
	V36.0Gy ≤ 10.0%	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
	V20.0Gy ≤ 30.0%	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
	V18.1Gy ≤ 40.0%	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
Urethra	D0.5cc ≤ 40.0Gy	61.1%	40.5Gy	55.6%	40.7Gy	69.4%	40.7Gy	61.1%	41.0Gy	52.8%	40.9Gy	72.2%	41.0Gy
	D50.0% ≤ 40.0Gy	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
Femoral Heads	Dmax ≤ 30.0Gy	100.0%	-	100.0%	-	97.2%	33.6Gy	100.0%	-	100.0%	-	86.1%	33.0Gy
	V28.0Gy ≤ 10.0cc	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
	Dmax ≤ 38.0Gy	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
Penile Bulb	D2.0% ≤ 28.5Gy	94.4%	28.8Gy	100.0%	-	83.3%	29.4Gy	88.9%	29.2Gy	100.0%	-	83.3%	29.8Gy
	Dmean ≤ 16.0Gy	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-
	V20.0Gy ≤ 3.0cc	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-	100.0%	-

Table 1. Summary of clinical goals in various scenarios

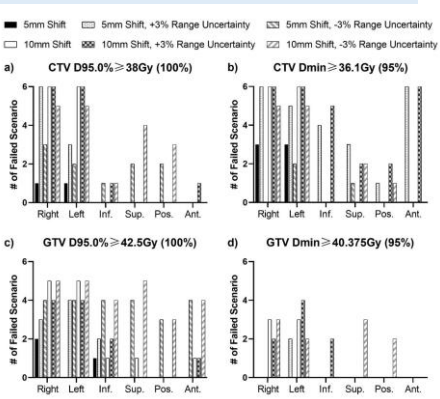

Figure 1. The occurrence of failed scenarios