Clinical validation of AI prostate SBRT plans: comparison to manual plans and generalization from 36.25 Gy to 40 Gy

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ABSTRACT TITLE

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PURPOSE/OBJECTIVE

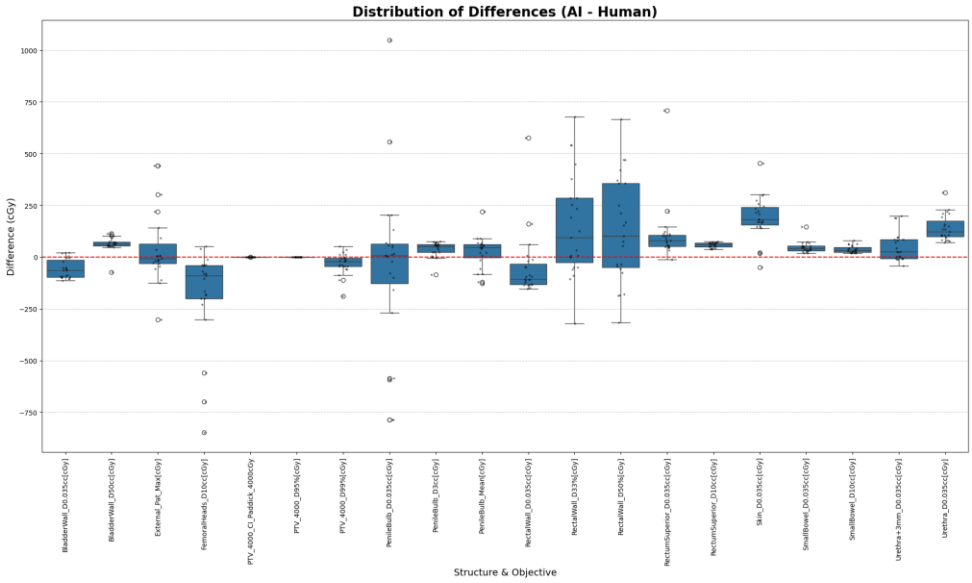
To assess institutional clinical readiness of TheraPanacea SmartPlan for prostate SBRT by comparing AI-generated plans with approved manual plans and evaluating generalization from the vendor-trained 36.25 Gy/5 regimen to the local 40 Gy/5 standard.

MATERIAL/METHODS

23 prostate SBRT cases were replanned with SmartPlan ("AI") using the same CT and clinical structure sets as the approved plans ("Human"). Prescriptions were 40 Gy in 5 fractions, with both Human and AI plans normalized to 100% dose covering 95% of the target volume; the AI model was originally trained on 36.25 Gy/5. Target metrics included PTV D95%, D99%, and the Paddick Conformity Index. Organ-at-risk (OAR) evaluation used the institutional SBRT constraint set, including urethra D0.035 cc and urethra+3 mm, bladder wall, rectal wall, femoral heads, penile bulb, and skin. Plan quality was summarized as deltas from constraint thresholds. Urethra contours were CT-based; MR was not available, and urethra/urethra+3 mm were not part of the vendor's model training targets.

RESULTS

AI plans achieved robust target coverage (D95% met in all cases; mean D99% was higher by 317 cGy) with conformality index comparable to Manual. The AI generalized to 40 Gy without retuning, preserving target coverage and producing favorable trade-offs for some OARs (mean femoral head sparing improved by ~179 cGy; modest reductions in bladder/rectal maxima). All AI plans consistently used 2 arcs compared to Human plans which varied between 2 and 3 arcs, with AI plans averaging 438 fewer monitor units and requiring less than 10 minutes for plan generation. Constraint deviations were concentrated in structures not included in model training: all AI plans exceeded the urethral D0.035 cc limit at 40 Gy by a mean of ~101 cGy, and urethra+3 mm/penile bulb contributed additional violations (93.5% of the total DVH objectives passed across 23 AI plans). AI plans also showed increased dose to skin and mid-to-low rectal dose regions.



Plan Performance Summary Statistics

Metric	Constraint_Value	Constraint_Type	Plan Type	Mean_Dose AI (TheraAuto)	Mean_Dose Human (Initial)	Median_Dose AI (TheraAuto)	Median_Dose Human (Initial)	Min_Dose AI (TheraAuto)	Min_Dose Human (Initial)	Max_Dose AI (TheraAuto)	Max_Dose Human (Initial)	Average Constraint Delta AI (TheraAuto)	Average Constraint Delta Human (Initial)	Average Difference (AI - Human)	Pass_Rate AI (TheraAuto)	Pass_Rate Human (Initial)
PTV_4000_CI_Paddick_4000cGy	1	Min Dose (>=)		0.9	0.9	0.9	0.9	0.8	0.8	0.9	0.9	-0.1	-0.1	0.0	100.0%	100.0%
PTV_4000_D95%[cGy]	4000	Min Dose (>=)		4000.0	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0	0.0	0.0	0.0	100.0%	100.0%
PTV_4000_D99%[cGy]	3600	Min Dose (>=)		3885.7	3916.7	3889.7	3919.8	3750.4	3836.4	3932.4	3954.7	-285.7	-316.7	-31.0	100.0%	100.0%
BladderWall_D0.035cc[cGy]	4200	Max Dose (<=)		4089.8	4146.3	4090.0	4157.2	4046.8	4042.2	4122.9	4194.2	+110.2	+53.7	-56.5	100.0%	100.0%
BladderWall_D50cc[cGy]	1825	Max Dose (<=)		267.1	202.3	202.2	132.4	91.1	43.7	762.5	835.6	+1557.9	+1622.7	+64.8	100.0%	100.0%
External_Pat_Max[cGy]	4280	Max Dose (<=)		4240.0	4259.3	4240.0	4259.3	4240.0	4259.3	4240.0	4259.3	+40.0	+20.7	-19.3	100.0%	100.0%
FemoralHeads_D10cc[cGy]	3000	Max Dose (<=)		1273.0	1451.6	1231.4	1453.6	1095.3	1074.2	1578.8	2067.0	+1727.0	+1548.4	-178.6	100.0%	100.0%
PenileBulb_D0.035cc[cGy]	3150	Max Dose (<=)		1319.1	1360.9	732.4	873.1	231.4	174.5	3685.8	3128.2	+1830.9	+1789.1	-41.8	87.0%	100.0%
PenileBulb_D3cc[cGy]	2500	Max Dose (<=)		275.0	236.9	259.3	215.2	128.0	76.3	448.1	509.2	+2225.0	+2263.1	+38.1	100.0%	100.0%
PenileBulb_Mean[cGy]	1000	Max Dose (<=)		400.7	376.1	345.5	323.4	154.7	99.1	889.2	898.5	+599.3	+623.9	+24.6	100.0%	100.0%
RectalWall_D0.035cc[cGy]	4200	Max Dose (<=)		3934.7	3983.9	3971.4	4058.5	3709.0	3287.4	4079.0	4161.5	+265.3	+216.1	-49.2	100.0%	100.0%
RectalWall_D33%[cGy]	3900	Max Dose (<=)		1585.9	1437.1	1589.8	1340.3	1270.1	911.5	1996.5	2135.4	+2314.1	+2462.9	+148.8	100.0%	100.0%
RectalWall_D50%[cGy]	2400	Max Dose (<=)		1146.5	1015.7	1148.9	945.5	857.3	482.8	1424.5	1572.5	+1253.5	+1384.3	+130.7	100.0%	100.0%
RectumSuperior_D0.035cc[cGy]	3000	Max Dose (<=)		412.8	302.7	388.7	285.2	151.6	101.0	1480.0	771.5	+2587.2	+2697.3	+110.1	100.0%	100.0%
RectumSuperior_D10cc[cGy]	2500	Max Dose (<=)		152.9	94.6	160.2	98.1	78.6	41.4	234.6	164.5	+2347.1	+2405.4	+58.3	100.0%	100.0%
Skin_D0.035cc[cGy]	2000	Max Dose (<=)		1139.2	950.2	1117.1	951.5	973.8	671.5	1325.2	1090.6	+860.8	+1049.8	+188.9	100.0%	100.0%
SmallBowel_D0.035cc[cGy]	2900	Max Dose (<=)		123.1	76.2	94.5	52.2	34.9	15.2	447.1	300.3	+2776.9	+2823.8	+46.9	100.0%	100.0%
SmallBowel_D10cc[cGy]	1950	Max Dose (<=)		88.0	50.5	73.3	39.2	29.3	11.2	240.4	159.2	+1862.0	+1899.5	+37.5	100.0%	100.0%
Urethra+3mm_D0.035cc[cGy]	4200	Max Dose (<=)		4180.9	4132.3	4161.7	4135.1	4099.6	4066.4	4353.5	4189.0	+19.1	+67.7	+48.6	82.6%	100.0%
Urethra_D0.035cc[cGy]	4050	Max Dose (<=)		4150.8	4010.2	4132.9	4014.6	4092.3	3959.4	4326.6	4048.8	-100.8	+39.8	+140.6	0.0%	100.0%

CONCLUSION

SmartPlan produced clinically competitive target coverage with successful generalization from 36.25 Gy/5 to 40 Gy/5, demonstrating improved femoral head sparing and planning efficiency (438 fewer MUs, <10-minute generation time). Urethral sparing represented the primary limitation, anticipated given CT-only delineation and exclusion of urethra structures from model training. Clinical implementation is feasible with two targeted improvements: (1) integration of MR-informed urethral contours into the planning workflow, and (2) vendor model updates explicitly optimizing urethral constraints. With implementation and deliverability testing, these results establish clinical viability across dose regimens, circumventing the resource-intensive need for institution-specific models.