

Robustness of Pelvic Nodal Target Coverage During Prostate SBRT with Intrafraction ExacTrac Dynamic Monitoring: Results from the AD ASTRA Trial

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Purpose

In the prospective phase II AD ASTRA trial, patients with high-risk prostate cancer received prostate stereotactic body radiotherapy (SBRT) with elective pelvic nodal irradiation and, when indicated, a simultaneous integrated boost (SIB) to involved pelvic lymph nodes. A two-step image-guidance strategy was used, consisting of initial pelvic alignment to bony anatomy for nodal target positioning followed by rigid prostate registration using implanted fiducial markers, with repeated intrafraction monitoring. We evaluated whether this strategy maintained adequate elective and involved pelvic nodal target coverage using the implemented 5 mm pelvic nodal planning target volume (PTV) margin and assessed the dosimetric impact of reducing this margin to 4 and 3 mm.

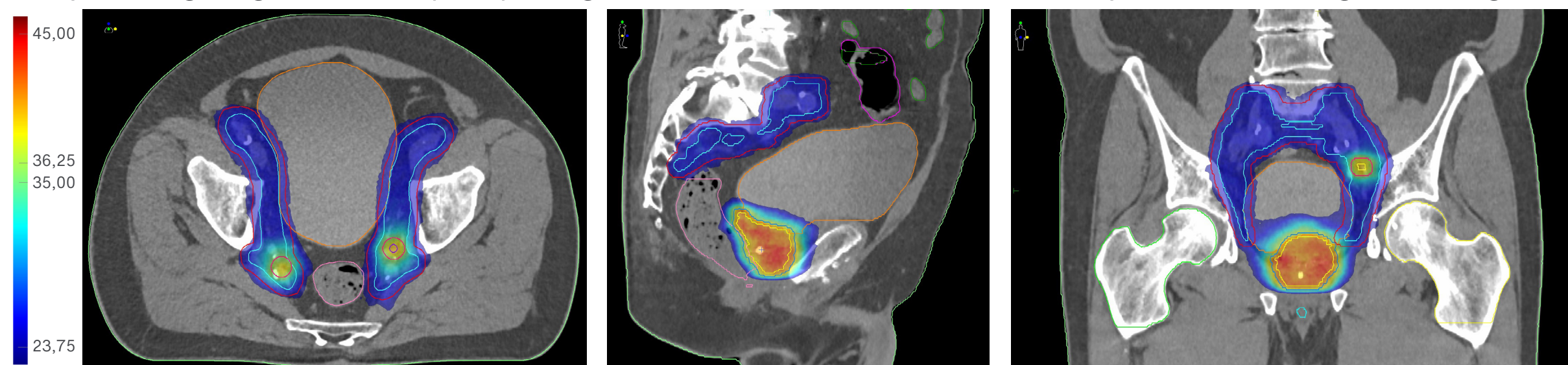


Figure 1 Isodose distribution in axial, sagittal, and coronal views for prostate SBRT (36.25 Gy) combined with elective pelvic nodal irradiation (25 Gy) and a simultaneous integrated boost to involved lymph nodes (35 Gy).

Materials and Methods

All 48 patients enrolled in the AD ASTRA trial were included. Patients received dual-arc VMAT delivering 36.25 Gy in five fractions to the prostate and 25 Gy in five fractions to the elective pelvic nodal volume (PTV_{pelvis_25}). Thirteen patients (27.1%) with cN1 disease additionally received a simultaneous integrated boost to involved pelvic lymph nodes (PTV_{nodal_35}) to 35 Gy in five fractions (**Figure 1**). Patient positioning used ExacTrac Dynamic stereoscopic X-ray imaging in a two-step workflow. Initial setup was based on pelvic bony anatomy using translational and rotational corrections, followed by rigid prostate registration using implanted fiducial markers. Only translational corrections were applied during prostate registration and were repeated throughout delivery of both VMAT arcs. Rotational corrections were not applied during prostate registration because rotation around the prostate reference could result in increasing positional displacement of pelvic nodal targets with increasing distance from the prostate. A total of 2,148 intrafraction stereoscopic image pairs were analysed. Recorded intrafraction translational shifts were applied in the treatment planning system to simulate their dosimetric impact on pelvic nodal target coverage. Fraction-specific dose distributions were recalculated and accumulated over all five fractions and compared with the original treatment plans. The robustness of the clinically implemented 5 mm pelvic nodal PTV margin was further explored by simulating reductions to 4 and 3 mm. This was achieved by applying additional 1 mm and 2 mm expansions to the original elective nodal CTV and involved nodal GTV, respectively. Protocol-specified coverage requirements were V23.75 Gy >95% for PTV_{pelvis_25} and V35 Gy >97% for PTV_{nodal_35}.

Clinical Outcomes

All patients completed radiotherapy as planned. In the overall AD ASTRA cohort, cumulative grade ≥ 2 genitourinary and gastrointestinal toxicity rates were 10.6% and 14.6%, respectively, while one patient (2.1%) experienced grade 3 gastrointestinal toxicity. No grade 4–5 acute radiotherapy-related toxicity was observed¹. These clinical outcomes provide context for the prostate and pelvic SBRT approach evaluated in this analysis.

Results

Analysis of 2,148 intrafraction stereoscopic image pairs showed that the 95th percentile of absolute translational displacement was below 4 mm in the lateral direction and approximately 5 mm in both the longitudinal and vertical directions (**Figure 2**). Dose recalculation incorporating the recorded intrafraction shifts demonstrated excellent pelvic nodal target coverage with the clinically implemented 5 mm margin. Mean simulated V100% was 99.8% (95% CI, 99.7–100%) for elective pelvic nodal targets and 99.6% (95% CI, 99.1–100%) for involved nodal metastases. A simulated reduction of the pelvic nodal PTV margin to 4 mm maintained protocol-compliant coverage for both elective and involved nodal targets, with mean V100% of 99.5% and 98.2%, respectively. Although coverage remained above the prespecified requirement, the reduction was more pronounced for involved nodal targets. Further reduction to a 3 mm margin maintained protocol-compliant coverage for elective pelvic nodes, with a mean V100% of 98.9%, but reduced coverage of involved nodal metastases below the prespecified requirement, with mean V100% decreasing to 96.0% (**Table 1**).

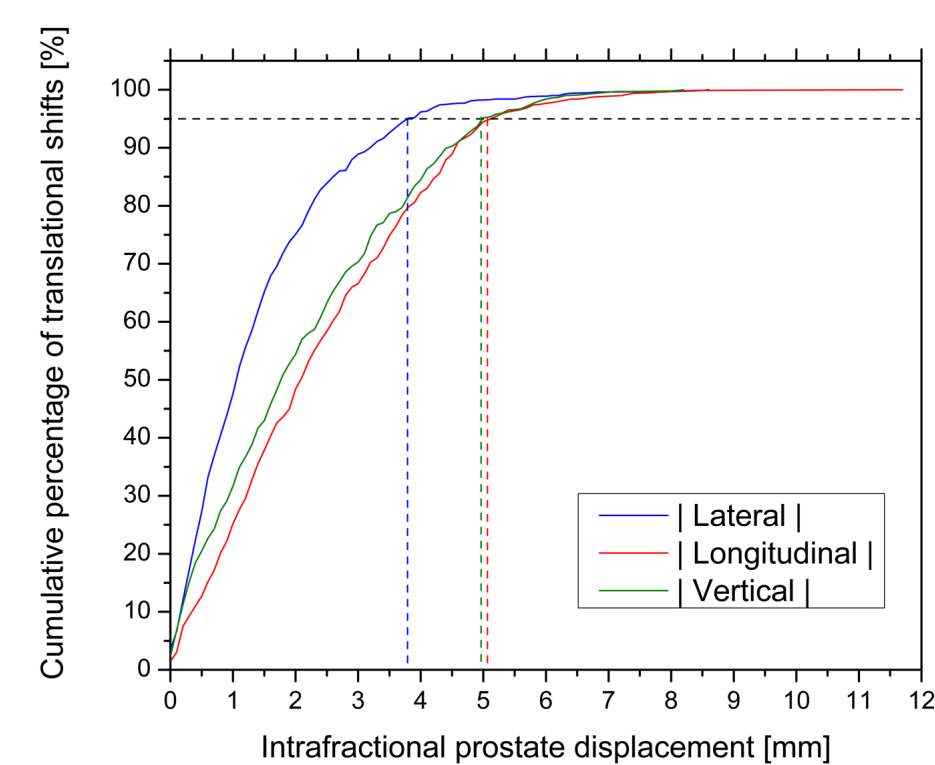


Figure 2 Cumulative distribution of intrafraction translational prostate displacements measured using ExacTrac Dynamic stereoscopic X-ray imaging from 2,148 image pairs. Displacements are shown in the lateral, longitudinal, and vertical directions, with dashed lines indicating the 95th percentile displacement values.

Conclusion

A two-step ExacTrac Dynamic image-guidance strategy combining initial pelvic bony anatomy alignment with intrafraction prostate registration using translational corrections only maintained excellent elective and involved pelvic nodal target coverage with the clinically implemented 5 mm PTV margin. A simulated reduction to 4 mm remained protocol-compliant for both nodal targets, although involved nodal coverage decreased more substantially than elective nodal coverage. Further reduction to 3 mm remained adequate for elective pelvic nodes but resulted in inadequate coverage of involved nodal targets receiving a simultaneous integrated boost. These findings support retaining a 5 mm pelvic nodal PTV margin, particularly when involved pelvic nodal disease is treated with an SIB.

References: ¹ Dubinský P, Belánová K, Tomková Z, Janičková N, Vojtek V. Akútna toxicita lokoregionálnej SBRT karcinómu prostaty v kombinácii s androgén-deprivačnou liečbou a apalutamidom. Onkológia (Bratisl.). 2026;21(S2):33.

	Elective pelvic lymph nodes CTV_evaluation (25 Gy)				Involved pelvic nodal metastases GTV (35 Gy)			
	D98 % [Gy] (Mean, 95 % CI)		V100 % [%] (Mean, 95 % CI)		D98 % [Gy] (Mean, 95 % CI)		V100 % [%] (Mean, 95 % CI)	
	PLANNED	MOTION SIMULATED	PLANNED	MOTION SIMULATED	PLANNED	MOTION SIMULATED	PLANNED	MOTION SIMULATED
5 mm PTV margin	25.2 Gy 25.2-25.3	25.4 Gy 25.3-25.4	99.5 % 99.3-99.6	99.8 % 99.7-100	37.3 Gy 37.1-37.5	36.4 Gy 36.0-36.7	100 % 100-100	99.6 % 99.1-100
4 mm PTV margin	25.2 Gy 25.2-25.2	25.3 Gy 25.3-25.4	99.4 % 99.2-99.5	99.5 % 99.3-99.8	37.1 Gy 36.9-37.3	35.8 Gy 35.5-36.2	100 % 99.9-100	98.2 % 96.9-99.5
3 mm PTV margin	25.2 Gy 25.1-25.2	25.2 Gy 25.1-25.2	99.2 % 99.0-99.3	98.9 % 98.5-99.3	36.7 Gy 36.5-36.9	35.3 Gy 35.0-35.8	99.9 % 99.6-100	96.0 %* 93.7-98.3

*Below the protocol-specified V35 Gy > 97% target coverage requirement.

Table 1 Planned and simulated pelvic nodal target coverage according to PTV margin. D98% and V100% for elective pelvic nodal targets receiving 25 Gy (defined as CTV25Gy excluding the 5 mm expansions around the prostate and involved nodal PTVs) and involved pelvic nodal metastases receiving 35 Gy according to the clinically implemented 5 mm PTV margin and hypothetical 4 mm and 3 mm margins. Simulated dosimetry incorporates the recorded intrafraction translational shifts. The protocol-specified coverage requirements were V23.75 Gy >95% for PTV_{pelvis_25} and V35 Gy >97% for PTV_{nodal_35}.