Dosimetric Impact of Baseline Shift Corrections During Online Adaptive Prostate MRgRT on Elekta Unity

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INTRODUCTION

MR-guided adaptive radiotherapy (MRgRT) on the 1.5T Elekta Unity MR-Linac enables real-time visualization and online plan adaptation for prostate treatments. During beam delivery, **intrafraction prostate motion**—predominantly inferior and posterior drift due to bladder filling—may necessitate **online correction**.

The baseline shift (**BLS**) function provides rapid geometric correction via **virtual couch shift** (segment aperture morphing), avoiding the time cost of full re-adaptation. However, BLS does not re-optimize the dose distribution, and it may **alter target and organ-at-risk** (OAR) **dosimetry** compared to the original adapted (**OA**) plan. An alternative is to continue treatment without correction (no correction, **NC**) if the target remains within the gating envelope or VOICE threshold is reduced.

The **dosimetric consequences** of these strategies—**BLS vs NC**—have not been systematically compared. Understanding the tradeoffs between target coverage preservation and OAR dose escalation across different shift magnitudes is essential for informing clinical decision-making during **MR-guided prostate treatments**.

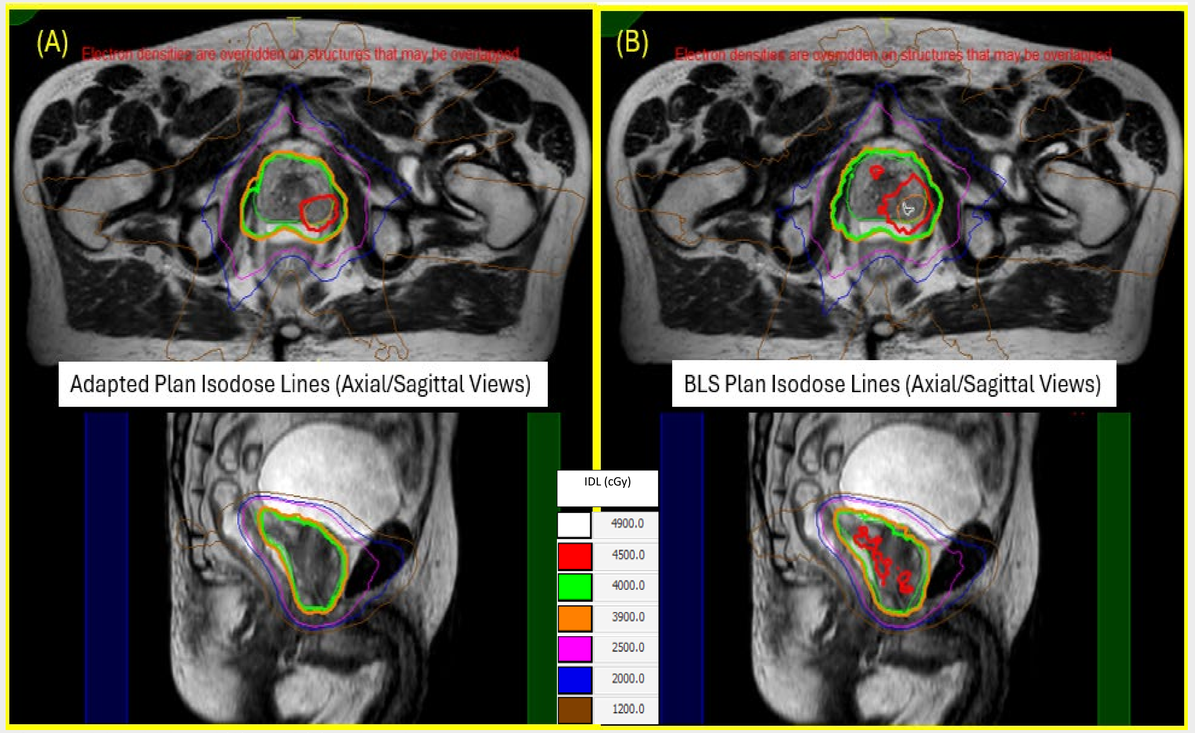

Figure 1. Original Adapted (A) vs BLS (B) Isodose Lines.

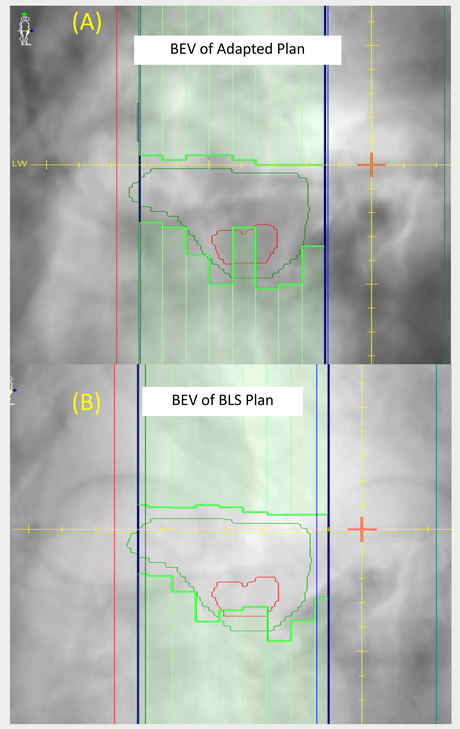

Figure 2. Adapted (A) vs BLS (B) BEV Showing MLC Aperture.

METHODS AND MATERIALS

18 prostate patients with **BLS** corrections selected:

- N=**9 prostate-only**: 4000cGy/5 fx
- N=**9 prostate plus DIL boost**: 4000/4500cGy/5 fx
- N=16/18 had rectal spacers
- Preparation: enema and 1/2 cup of water
- CTV-to-PTV_Prostate margin: 3 mm all cases
- GTV-to-PTV_DIL margins: range 0–3 mm (0mm N=6, 2mm N=1, 3mm N=2)

42 BLS events observed:

- **39 analyzed** (Post/Inf shifts)

For each event, 3 scenarios evaluated:

i. **original OA** plan
ii. delivered **BLS** plan *
iii. simulated **NC** plan * (OA plan recalculated with the BLS-induced shifts applied to the anatomy representing treatment continuation without online correction)

* Scenarios ii/iii: anatomical drift simulated by rigidly shifting the target/OARs contours using the BLS target displacement. External contour not shifted.

Results stratified by maximum translational **shift** in the S-I or A-P direction:

- 2 mm (0.1–2.4 mm)
- 3 mm (2.5–3.4 mm)
- 4 mm (3.6- 5.8mm)

Evaluated metrics:

- Target: D95%/Dmean/D0.035cc
- Rectum: D0.035cc/V3850cGy/V2900cGy
- Bladder: D0.035cc/V3700cGy
- Urethra: D0.035cc

Relative and absolute differences reported as **mean±SD**.

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RESULTS

Mean shifts at the time of BLS: +0.1±1.4 mm (**Lt**), −2.9±1.0 mm (**Inf**), and −2.4±0.7 mm (**Post**), predominantly **inf/post drift**.

Tables 1 and 2 summarize the **dosimetric comparison** of target and OAR structures across all three scenarios (**OA, BLS, NC**).

BLS vs OA plans:

- **Preserved** target coverage
- **Increased CTV Dmean** and **PTV hotspots**
- **Increased OAR doses**

NC vs OA plans:

- **Decreased** target coverage
- **Decreased rectal** dose
- **Increased Bladder**
- **Urethra** within guidelines

Figure 1 shows a **dose distribution comparison** between OA and BLS plans, demonstrating a general **expansion of the high-dose cloud** (4500–4900 cGy) with BLS. **Figure 2** illustrates the mechanism: after Segment Aperture Morphing (SAM), the MLC aperture shifts relative to anatomy, increasing GTV exposure and surrounding tissue dose.

Constraint violations: 25/39 **BLS** plans (**64%**) exceeded at least 1 departmental constraint vs 13/39 **NC** plans (33%).

Shift size vs metrics: No trend.

In summary, BLS vs NC (mean % Δ from OA, at 2/3/4mm):

	BLS	NC
CTV D95%	+0.45 /+0.82 / +0.84%	−0.75 / −1.97 / −1.90%
PTVPros D0.035cc	+1.99 / +3.92 / +3.25%	+0.63 / +0.03 / +1.01%
Urethra D0.035cc	+3.77 / +2.92 / +3.18%	+0.53 / +0.50 / −0.04%
Rectum D0.035cc	+1.59 / +2.42 / +1.84%	−7.10 / −9.82 / −7.15%
Bladder D0.035cc	+2.14 / +2.32 / +1.83%	+1.55 / +2.47 / +4.25%

Structure	Metric	Limit (cGy)	Shift	OA	BLS	NC	Δ BLS - OA	Δ NC - OA
GTV	D95%	≥ 4500	**2mm** (n=5)	4534.7 ± 28.3	4548.3 ± 50.2	4470.9 ± 44.6	0.30 ± 1.10%	−1.41 ± 1.20%
			3mm (n=8)	4529.7 ± 45.2	4549.4 ± 38.7	4369.0 ± 82.3	0.43 ± 1.33%	−3.55 ± 1.93%
			4mm (n=4)	4576.1 ± 21.4	4555.6 ± 35.8	4323.8 ± 98.7	−0.44 ± 1.22%	−5.52 ± 2.22%
CTV	D95%	≥ 4000	**2mm** (n=8)	4073.3 ± 18.5	4091.9 ± 32.8	4042.6 ± 49.8	0.45 ± 0.89%	−0.75 ± 0.97%
			3mm (n=21)	4017.5 ± 40.7	4050.1 ± 32.5	3940.1 ± 48.2	0.82 ± 1.54%	−1.97 ± 1.72%
			4mm (n=10)	4028.3 ± 45.6	4061.9 ± 54.2	3949.8 ± 28.6	0.84 ± 0.93%	−1.90 ± 2.54%
	Dmean	≥ 4000	**2mm** (n=8)	4225.1 ± 83.6	4289.0 ± 94.0	4226.4 ± 86.8	1.51 ± 0.95%	0.02 ± 0.31%
			3mm (n=21)	4169.0 ± 52.2	4247.3 ± 37.7	4147.8 ± 55.5	1.74 ± 1.43%	−0.51 ± 0.39%
			4mm (n=10)	4170.4 ± 61.7	4249.6 ± 59.8	4141.9 ± 51.2	1.79 ± 0.72%	−0.70 ± 0.41%
PTVDIL	D0.035cc	< 4800	**2mm** (n=5)	4665.9 ± 71.8	4722.6 ± 92.3	4650.7 ± 68.5	1.20 ± 1.30%	−0.34 ± 0.80%
			3mm (n=8)	4768.7 ± 55.3	4857.7 ± 68.4	4760.9 ± 52.8	1.86 ± 1.49%	−0.17 ± 0.85%
			4mm (n=4)	4805.1 ± 24.6	4877.9 ± 48.2	4780.9 ± 37.5	1.51 ± 1.27%	−0.51 ± 0.75%
PTVPros	D0.035cc	4280–4400	**2mm** (n=3)	4400.0 ± 50.8	4487.1 ± 29.5	4427.8 ± 71.0	1.99 ± 0.88%	0.63 ± 0.56%
			3mm (n=13)	4359.7 ± 64.5	4544.1 ± 131.0	4360.9 ± 66.1	3.92 ± 2.43%	0.03 ± 0.45%
			4mm (n=10)	4404.7 ± 57.4	4547.8 ± 75.1	4414.0 ± 67.2	3.25 ± 0.54%	1.01 ± 0.85%

Table 1. Dosimetric Comparison of Target Structures – average over ALL CASES.

Structure	Metric	Limit	Shift *	OA	BLS	NC	Δ BLS - OA	Δ NC - OA
Rectum	D0.035cc	< 4120cGy	**2mm** (n=8)	3931.7 ± 150.2	3994.1 ± 176.8	3655.4 ± 230.5	1.59 ± 2.26%	−7.10 ± 3.00%
			3mm (n=21)	3883.1 ± 232.7	3981.6 ± 218.4	3511.1 ± 358.9	2.42 ± 2.07%	−9.82 ± 6.29%
			4mm (n=10)	4046.4 ± 98.6	4120.3 ± 117.2	3757.8 ± 278.4	1.84 ± 1.74%	−7.15 ± 5.86%
	V3850cGy	< 1-2cc **	**2mm**	0.4 ± 0.3	0.6 ± 0.4	0.1 ± 0.1	0.16 ± 0.23 cc	−0.38 ± 0.55 cc
			3mm	0.5 ± 0.4	1.0 ± 1.4	0.2 ± 0.2	0.49 ± 1.05 cc	−0.31 ± 0.37 cc
			4mm	0.9 ± 0.9	1.0 ± 1.2	0.2 ± 0.3	0.15 ± 0.39 cc	−0.70 ± 0.83 cc
	V2900cGy	< 10-30%	**2mm**	7.6 ± 2.6	8.1 ± 3.0	3.9 ± 2.5	6.88 ± 11.45%	−53.75 ± 15.54%
			3mm	9.3 ± 4.8	10.5 ± 5.6	4.7 ± 4.5	16.13 ± 23.92%	−64.83 ± 28.88%
			4mm	8.9 ± 5.8	9.6 ± 5.5	3.7 ± 5.5	9.46 ± 10.68%	−62.75 ± 28.76%
Bladder	D0.035cc	< 4200-4350cGy	**2mm**	4218.5 ± 79.4	4307.6 ± 49.3	4283.9 ± 82.1	2.14 ± 1.60%	1.55 ± 0.52%
			3mm	4152.0 ± 68.5	4254.2 ± 83.7	4253.2 ± 117.4	2.32 ± 2.49%	2.47 ± 1.49%
			4mm	4102.1 ± 88.3	4177.9 ± 102.5	4272.5 ± 69.8	1.83 ± 2.01%	4.25 ± 3.24%
	V3700cGy	< 10-20cc **	**2mm**	7.6 ± 1.8	8.8 ± 1.7	12.1 ± 1.6	1.18 ± 1.44 cc	4.46 ± 0.44 cc
			3mm	7.9 ± 3.5	9.6 ± 5.8	15.4 ± 6.2	1.48 ± 3.10 cc	7.44 ± 4.05 cc
			4mm	6.1 ± 3.7	6.8 ± 3.8	15.0 ± 5.4	0.71 ± 1.12 cc	8.85 ± 3.79 cc
Urethra	D0.035cc	< 4200-4350cGy	**2mm**	4215.5 ± 42.6	4374.2 ± 95.8	4237.9 ± 55.3	3.77 ± 2.54%	0.53 ± 0.71%
			3mm	4231.3 ± 67.2	4361.8 ± 88.5	4252.7 ± 89.6	2.92 ± 3.24%	0.50 ± 1.32%
			4mm	4206.6 ± 36.4	4340.4 ± 105.3	4204.7 ± 49.2	3.18 ± 1.84%	−0.04 ± 1.33%

* number of instances (n) are the same for all OARs and shift combination.
** reported as absolute change.

Table 2. Dosimetric Comparison of OAR Structures – average over ALL CASES

CONCLUSIONS

Correcting intrafraction motion with BLS represents a **clinical tradeoff**. **BLS preserved target coverage but increased target mean/hotspot and OAR doses**—most notably urethra. **NC reduced target coverage and increased bladder dose while maintaining urethral tolerance**. Because drift typically occurs mid-to-late fraction, the **fraction-averaged** impact may be **smaller than reported full-plan differences**.

These findings suggest **selective correction strategies**: NC may be acceptable for smaller shifts unless coverage or bladder dose is concerning; BLS should be considered otherwise, unless urethral hotspot warrants re-adaptation. **Further investigation into the fraction-delivered dosimetric impact** is needed to establish guidelines for when to apply BLS, continue without correction (NC), or re-adapt to preserve original plan quality.