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Impact of Structured Visual Feedback on Bladder Volume Consistency in Prostate EBRT: A Medical Physics 3.0 inspired trial.

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ABSTRACT

Purpose: A single institution clinical trial evaluated the efficacy of structured patient education and individualized CBCT-based visual feedback on the consistency and magnitude of bladder volume relative to the planning simulation baseline for prostate EBRT patients.

Methods: Data from 35 patients was analyzed (23 controls, 12 subjects). The subjects received individualized education about the importance of both total bladder volume and volume consistency during their treatment course. Sessions were conducted by medical physics learners. Additionally, they received individualized weekly feedback sessions using their daily CBCTs, overlaid with their simulation contours. Patient bladder volumes were manually contoured on all daily CBCTs (MIM Maestro). Anatomical variation was accounted for by normalizing each patient to their own simulation baseline ($V_{norm}= V_{tx}/V_{sim}$). Patient specific median normalized volumes were utilized to assess consistency. Variability was measured via standard deviation from individual normalized volumes. Inter-group comparisons were performed using Welch's t-test and Cohen's d.

Results: The subjects receiving feedback demonstrated significantly higher bladder volume consistency compared to the controls (mean normalized volume: 1.052 vs. 0.766, p = 0.0131) with a large effect size (Cohen's d = 0.88). They also exceeded their simulation volumes during 51.5% of their fractions, compared with 25.7% for the control group (p < 0.0322). Notably, the intentional increase in volume did not significantly increase inter-fraction variability (p = 0.475, d = 0.24), which suggests that the feedback improved patient bladder volume without sacrificing reproducibility between fractions.

Conclusion: Visual feedback provided to patients in clinic with existing medical physics learners is a low-resource strategy that significantly improves protocol adherence. In addition to the learning benefits provided to the medical physics learners, the benefits to the patients were measurable. It has already been established that Improved bladder volumes, particularly when they are above 200ml, provides a dose sparing effect to OARSs, this intervention has been shown to consistently improve bladder volume. Additionally, there was no statistically significant increase in increasing inter-fractional variability or disrupting standard clinical workflow.

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INTRODUCTION

Our pilot study was conducted to evaluate the efficacy of structured weekly feedback sessions on patient bladder fullness and consistency during prostate cancer External Beam Radiation Therapy (EBRT). EBRT treatment delivery requires a plan that delivers the prescribed dose to the target while limiting exposure to adjacent organs-at-risk (OARs). The bladder's close proximity to the prostate, and the planning target volume (PTV) expansions required to account for positional variability, are of clinical concern. Unfortunately, the combination of these factors often results in the bladder receiving substantial doses resulting in post-treatment genitourinary toxicities such as hematuria and incontinence.

Full bladder protocols, which displace the bladder superiorly and anteriorly, are typically implemented to mitigate the risks. Protocol adherence is frequently inconsistent, which is thought to be a result of limited patient understanding of the dosimetric benefits.

Our Medical Physics 3.0 inspired pilot study provided structured weekly educational feedback sessions. These sessions were conducted utilizing daily cone-beam computed tomography (CBCT) overlays of the patients' simulation contours. The intervention demonstrated that a patient-centric feedback model improved relative total volume during treatments ($V_{norm} = V_{tx}/V_{sim}$) without increasing inter-fraction variability.

METHODS AND MATERIALS

Data from 35 patients was analyzed (23 controls, 12 subjects). The subjects received individualized education about the importance of both total bladder volume and volume consistency during their treatment course.

Sessions were conducted by medical physics learners. Additionally, they received individualized weekly feedback sessions using their daily CBCTs, overlaid with their simulation contours. Patient bladder volumes were manually contoured on all daily CBCTs (MIM Maestro).

Anatomical variation was accounted for by normalizing each patient to their own simulation baseline ($V_{norm} = V_{tx}/V_{sim}$). Patient specific median normalized volumes were utilized to assess consistency. Variability was measured via standard deviation from individual normalized volumes. Inter-group comparisons were performed using Welch's t-test and Cohen's d.

NORMALIZED VOLUME FORMULA

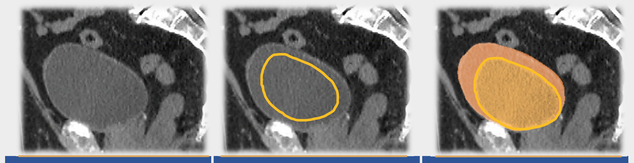
$$V_{norm} = \frac{V_{tx}}{V_{sim}}$$

RESULTS

The subjects receiving feedback demonstrated significantly higher bladder volume consistency compared to the controls (mean normalized volume: 1.052 vs. 0.766, p = 0.0131) with a large effect size (Cohen's d = 0.88).

They also exceeded their simulation volumes during 51.5% of their fractions, compared with 25.7% for the control group (p < 0.0322).

Notably, the intentional increase in volume did not significantly increase inter-fraction variability (p = 0.475, d = 0.24), which suggests that the feedback improved patient bladder volume without sacrificing reproducibility between fractions.



DAILY CBCT:	MIM OVERLAYS:	WEEKLY SESSIONS:
The primary feedback source.	Comparing current state and simulation.	Physics-led coaching

Figure 1. Conceptualization of Structured Patient Feedback Sessions.

Table 1. Statistical Study.

METRIC	CONTROL GROUP (n = 23)	ON-TRIAL GROUP (n = 12)	P-VALUE	EFFECT SIZE (Cohen's d)
Fractions Exceeding Sim Volume (%)	25.7%	51.5%	0.0322	N/A
Mean Normalized Volume (V_{norm})	0.766	1.052	0.0131	0.88
Inter-fraction Variability (σ_{norm})	0.289	0.341	0.475	0.24

DISCUSSION

Structured visual feedback significantly improves patient bladder filling protocol adherence. Those patients who received individualized education demonstrated significantly higher mean normalized bladder volumes(V_{norm}) of 1.052 in comparison with the mean normalized bladder volumes (V_{norm}) of the control group 0.766 ($p = 0.0131$) and here was a large size effect (Cohen's $d = 0.88$), underscoring the positive clinical impact of the intervention.

Subjects who received intervention were twice as likely as those who did not to exceed their simulation volumes (51.5% of fractions vs. 25.7% for controls, p < 0.0322). This intentional increase in patient bladder volume did not lead to a significant increase in the inter-fraction variability (p = 0.475). This suggests that feedback sessions empowered patients, enabling them to achieve higher volumes while maintaining consistency

For clinics with medical physics learners, this intervention represents a low-resource strategy implementable with minimal impact to clinical workflows. Improving bladder fullness is established as a mechanism facilitating dose sparing to OARs. Despite the small cohort, our findings suggest further investigation is warranted.

CONCLUSIONS

Providing visual feedback to patients is a low-resource strategy that significantly improves protocol adherence.

Improved bladder volumes are known to facilitate dose sparing to the OARs, and this intervention has been shown to do so without increasing inter-fractional variability or disrupting standard clinical workflow.

PATIENT NORMALIZED BLADDER VOLUMES

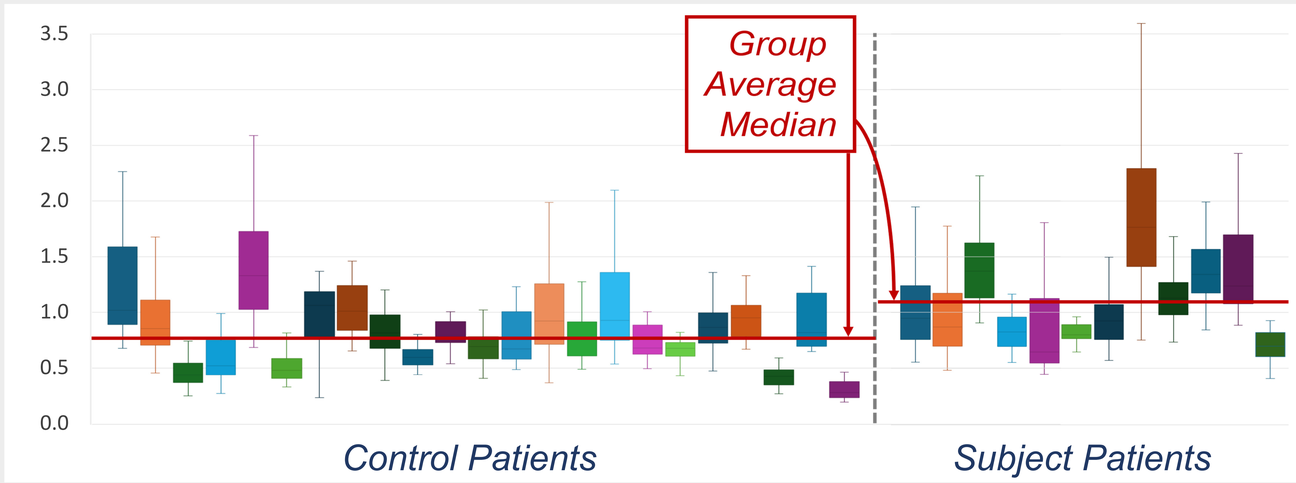


Chart 1. Control and Subject Patient Normalized Bladder Volume Comparison.

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