Evaluation of Immobilization Device Performance In Reducing Intrafraction Motion for Linac-Based Upper Spine SBRT Using Mid- and Post-Treatment CBCT

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ABSTRACT

Purpose: Spine SBRT involves steep dose gradients near critical organs at risk, making treatments highly sensitive to intrafraction motion. This study evaluated the performance of immobilization devices used for LINAC-based upper spine (T2 and above) SBRT by using mid- and post-treatment CBCT imaging as a surrogate for intrafraction motion.

Methods: 42 patients treated with upper spine SBRT between May 2023 and December 2025 at a tertiary academic center were retrospectively analyzed. The institutional SBRT workflow included a pre-treatment CBCT for initial alignment, a mid-treatment CBCT acquired between treatment arcs for repositioning as needed, and a post-treatment CBCT to assess patient motion during the latter portion of treatment. Over this period, three head-and-shoulder immobilization masks were used for upper spine SBRT: a Klarity White S-type, Klarity Green P-type, and Klarity Blue S-type mask. The treatment database was queried to identify eligible spine SBRT patients. Translational and rotational shifts from mid- and post-treatment CBCTs were extracted for each treatment fraction, and the immobilization device and treated vertebral level were obtained from treatment records. A total of 333 CBCT images were analyzed and stratified by vertebral level and immobilization device.

Results: Translational and rotational tolerances of 2 mm and 1° were applied based on institutional practice. Among immobilization devices, the Klarity White S-type mask demonstrated the poorest performance, with 28.6% and 26.7% of patients exceeding either translational or rotational tolerance on mid- and post-treatment CBCT, respectively. The Klarity Green P-type mask performed best, with 3.6% and 3% of patients exceeding tolerance on mid- and post-treatment CBCT respectively.

Conclusion: Immobilization device choice significantly impacts intrafraction motion for upper spine SBRT, and continuous longitudinal tracking of patient localization is an important QA tool for practice improvement for Spine SBRT programs.

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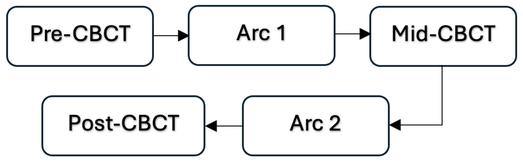
INTRODUCTION

SBRT treatments show significant results in reducing pain and improving local control for metastatic disease to the spine. Additionally, due to the rapid dose falloff, reirradiation is feasible in the oligometastatic setting. The reduction of intrafraction movement is vital to reduce dose to critical organs such as the spinal cord.

One way to monitor and correct for intrafraction motion is to use CBCT imaging throughout the treatment and shift the patient back to the treatment position.



Upper spine (T2 and above) LINAC-based SBRT treatments introduce additional complications as a standard VacLoc bag is not sufficient for immobilization. There are several available types of masks, with different connection mechanisms and rigidity. This work retrospectively analyzed the motion during upper spine SBRT treatments reported by the mid- and post-CBCT shifts and stratified the shifts based on the mask type, Klarity Blue S-Type, Klarity Green P-Type, and Klarity White S-Type, as shown in Figure 1. Based on this shift analysis, clinical procedures can be updated to reflect the best practices seen in our clinic.

METHODS AND MATERIALS

Upper spine SBRT patients undergoing treatment from May 2023 through December 2025 were retrospectively queried from the institution's treatment database and categorized based on vertebral level and immobilization device. The reported shifts on the day of treatment for mid- and post-CBCT imaging were analyzed and stratified based on the type of shift, translational (lateral, longitudinal, and vertical) or rotational (pitch, roll, and yaw), and immobilization device, Klarity Blue S-Type, Klarity Green P-Type, and Klarity White S-type. Tolerances were set at 2 mm and 1 degree and the number of images that exceeded tolerance translationally, rotationally, and both were counted and recorded for each immobilization device.

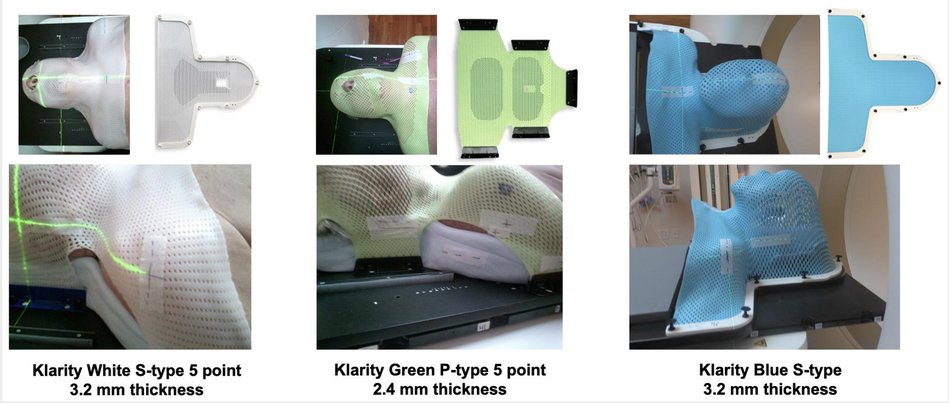


Figure 1: Klarity immobilization masks used for the treatment of upper spine SBRT patients within the institution's clinic

RESULTS

The Klarity White S-Type Mask had the poorest performance with 20.69% of patients exceeding a rotational tolerance on mid- or post-treatment CBCT.

The Klarity Blue S-Type Mask performed well, with only 2.06% of patients exceeding either a rotational or translational tolerance on mid- or post-treatment CBCT. The Klarity Green P-Type Mask performed the best with 1.639% of patients exceeding rotational or translational tolerance.

The Klarity White S-Type mask exceeded rotational tolerance most often, while the other two masks saw equal amounts of of tolerance translationally and rotationally.

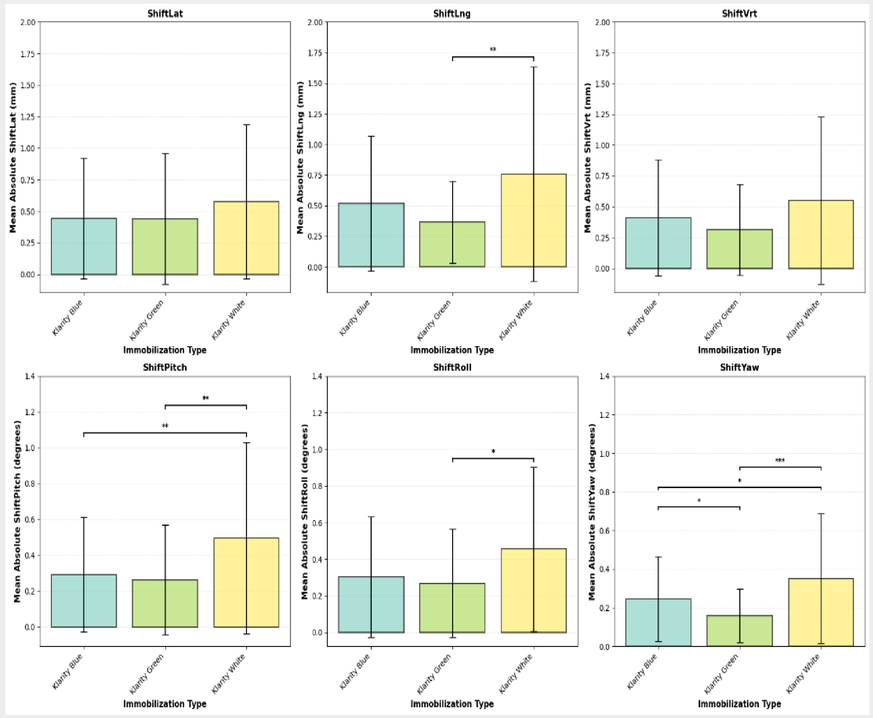


Figure 2: Reported translational and rotational shifts for each immobilization device over all CBCT images

CBCT Images Exceeding Tolerance for Upper Spine SBRT Immobilization Devices

	Klarity Blue S-Type		Klarity Green P-Type		Klarity White S-Type	
Total Number of Images	243		61		29	
	Count	Percentage	Count	Percentage	Count	Percentage
Tolerance Exceeded, Translational Only	5	2.058%	1	1.639%	0	0.000%
Tolerance Exceeded, Rotational Only	5	2.058%	1	1.639%	6	20.690%
Tolerance Exceeded, Both Translational and Rotational	1	0.412%	0	0.000%	2	6.897%

Table 1: Translational and rotational shifts for each immobilization device that exceeded tolerances of 2 mm and 1 degree.

DISCUSSION

Significant differences can be seen in patient shifts during treatment depending on the immobilization device. Additionally, a larger percentage of upper spine SBRT patients were out of tolerance during the mid-CBCT than in the post-CBCT.

These results indicate the need for improving the motion management of upper spine SBRT patients, particularly towards the beginning of treatment when they are not settled. The addition of a verification CBCT before treatment may catch large patient motion before treatment begins, reducing the potential intrafraction motion further.

CONCLUSIONS

This study provides a systematic, large-sample evaluation of immobilization device performance for linac-based upper spine (T2 and above) SBRT using routine clinical CBCT data, including mid- and post-treatment imaging and directly compares multiple commercially available immobilization devices under identical clinical workflows and quantifies intrafraction motion across vertebral levels. The findings demonstrate clinically meaningful differences in immobilization performance and highlight the importance of mid-treatment verification imaging for patients with higher risks of motion. These results support evidence-based selection of immobilization devices and inform workflow optimization in high-throughput SBRT clinics, with the potential to improve target coverage, reduce intrafraction uncertainty, and enhance treatment safety.

REFERENCES

1. Alexander DA, Scheuermann R, Messing I, Kassaee A, Hubley E, Koger B, Anamalayil S, Hassankhani A, Freeman CW, Malhotra N, Peters GW, Butala AA. Evaluating the dosimetric impact of intrafraction shifts on critical OAR doses for spine SBRT using an In-House simulator. Tech Innov Patient Support Radiat Oncol. 2026 Jan 8;37:100378. doi: 10.1016/j.tipsro.2026.100378. PMID: 41583860; PMCID: PMC12830219.