Feasibility of Surface-Guided Radiotherapy for Setup and Intrafraction Monitoring in Brain IMRT Using Open-Face Masks

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ABSTRACT

Surface-guided radiotherapy (SGRT) with open-face thermoplastic masks has the potential to improve patient comfort, streamline treatment setup, and provide continuous intrafraction motion monitoring during brain radiotherapy. This study evaluated the feasibility and accuracy of SGRT for routine brain IMRT and investigated whether different immobilization devices influence monitoring performance. Phantom measurements demonstrated stable monitoring accuracy following CBCT-based reference surface capture, with no clinically meaningful differences between flat baseplate and pituitary board immobilization. These findings support the use of SGRT as an additional safety layer alongside daily image guidance and provide the foundation for future clinical implementation and potential PTV margin reduction.

INTRODUCTION

Accurate patient positioning is essential for brain intensity-modulated radiation therapy (IMRT), where highly conformal dose distributions require precise treatment delivery. Daily cone-beam CT (CBCT) is widely used for patient localization; however, it provides only a snapshot of patient position and cannot detect motion that occurs during treatment. Surface-guided radiotherapy (SGRT) has emerged as an effective non-ionizing technology for patient positioning and real-time motion monitoring. When combined with open-face thermoplastic masks, SGRT offers several clinical advantages over conventional closed-mask immobilization, including improved patient comfort by reducing anxiety and claustrophobia, more efficient initial patient setup, reduced need for repeated setup corrections, and continuous intrafraction motion monitoring throughout treatment delivery. Rather than replacing image guidance, SGRT serves as an additional safety layer that complements daily CBCT by detecting unexpected patient motion during treatment.

Although SGRT has been widely adopted for cranial stereotactic radiosurgery (SRS) and stereotactic radiotherapy (SRT), evidence supporting its routine application for conventional brain IMRT remains limited. Furthermore, different immobilization devices, such as flat baseplates and pituitary boards, may influence camera visibility and surface tracking accuracy, but their effects have not been well characterized.

The purpose of this study was to evaluate the feasibility and accuracy of SGRT for patient setup and intrafraction motion monitoring during routine brain IMRT using open-face thermoplastic masks. We also investigated whether immobilization device type affects monitoring performance and developed a practical clinical workflow integrating SGRT with daily CBCT.

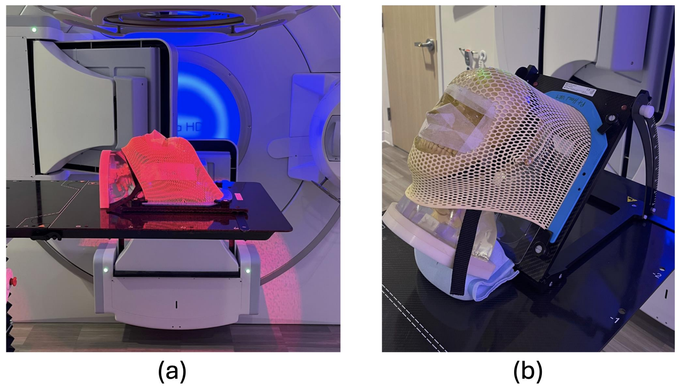
METHODS AND MATERIALS

Phantom experiments were performed using an anthropomorphic head phantom immobilized with open-face thermoplastic masks mounted on two commonly used immobilization devices: a flat baseplate and a pituitary board (Figure 1).

A facial region of interest (ROI) was created for SGRT tracking using stable facial anatomy extending from the upper forehead to the nasal bridge and bilateral cheeks while excluding the eye region to minimize false motion caused by blinking (Figure 2).

Initial patient setup was performed using SGRT with translational and rotational tolerances of 0.5 mm and 0.5°, respectively. Final positioning was verified using CBCT, after which the SGRT reference surface was recaptured to establish the monitoring baseline for intrafraction motion tracking. System repeatability was evaluated with advanced camera optimization enabled.

METHODS AND MATERIALS



(a) (b)

Figure 1. Phantom immobilization using open-face thermoplastic masks mounted on two different immobilization devices evaluated in this study. (a) Open-face thermoplastic mask mounted on flat baseplate, and (b) Open-face thermoplastic mask mounted on pituitary board

Figure 2. Example of facial tracking ROI used for SGRT monitoring. Rigid anatomical regions such as the nasal bridge and cheeks were prioritized for stable surface tracking, while the eye region was excluded to minimize false motion detection due to blinking.

The study evaluated:

- SGRT system repeatability
- Setup agreement between SGRT and CBCT
- Influence of immobilization device
- Stability after CBCT reference recapture
- Effect of couch rotation on monitoring accuracy

Measured translational deviations were compared between immobilization systems, and monitoring performance was assessed throughout simulated treatment delivery.

RESULTS

The SGRT system demonstrated excellent repeatability, with positional variation remaining below 0.5 mm near isocenter. Following CBCT-based couch correction and reference surface recapture, residual monitoring errors remained within ±0.5 mm, indicating stable intrafraction monitoring performance. Average translational differences between SGRT-based setup and CBCT alignment were approximately 1.5 mm for the flat baseplate and 1.7 mm for the pituitary board, demonstrating similar setup performance between immobilization devices. No clinically meaningful differences were observed in monitoring accuracy after reference recapture.

Couch rotation introduced a maximum additional uncertainty of approximately 1.5 mm, which remained within clinically acceptable limits for routine brain IMRT monitoring.

Based on these findings, a proposed clinical workflow integrating SGRT with daily CBCT was developed to facilitate routine brain IMRT while maintaining continuous intrafraction motion monitoring (Figure 3).

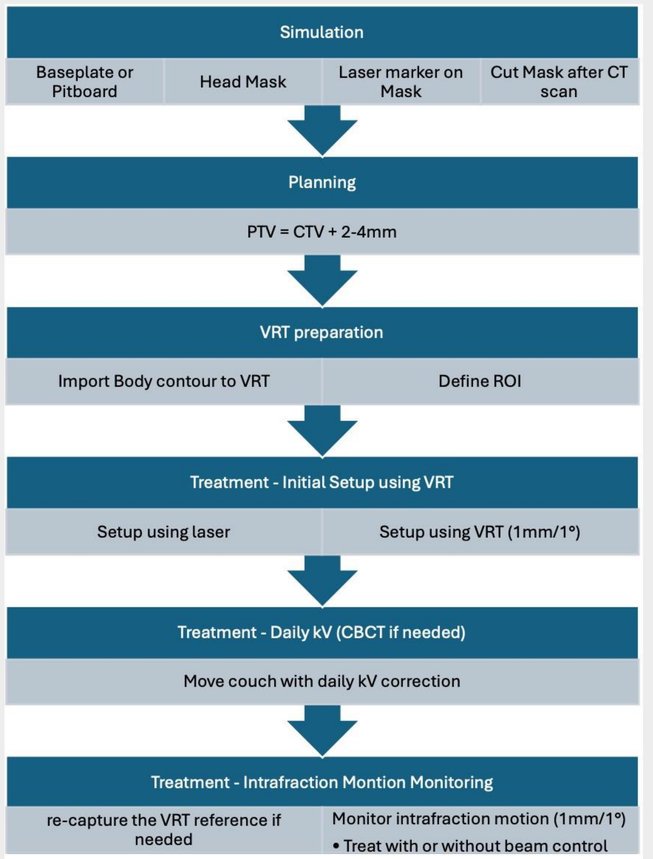


Figure 3. Suggested clinical workflow for brain IMRT incorporating SGRT, including open-face mask simulation, SGRT-based initial setup (1 mm / 1° tolerance), CBCT-based final positioning, post-correction reference surface recapture, and continuous intrafraction motion monitoring with or without beam control. SGRT is used as a safety monitoring layer in addition to daily image guidance.

CONCLUSIONS

This study demonstrates that SGRT is a feasible and reliable tool for patient setup verification and intrafraction motion monitoring during routine brain IMRT using open-face thermoplastic masks.

Monitoring performance was comparable between flat baseplate and pituitary board immobilization systems, indicating minimal dependence on immobilization device selection.

When integrated with daily CBCT and post-correction reference surface capture, SGRT provides stable real-time monitoring throughout treatment while serving as an additional safety layer rather than replacing image guidance. The use of open-face masks may also improve patient comfort and facilitate a more efficient clinical workflow by reducing setup time and minimizing the need for repeated positioning.

These phantom results support the clinical implementation of SGRT-assisted brain IMRT. Future work will evaluate patient motion data to further validate this workflow and investigate the potential for reducing PTV margins in routine clinical practice.

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