Dosimetric Comparison between SGRT- and RPM-Based DIBH APBI for Left-Sided Breast Patients

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ABSTRACT

Purpose: Accurate breath-hold reproducibility is critical in left-sided breast irradiation to reduce cardiac and lung dose, and differences in motion management techniques may influence delivered dose accuracy. The purpose of this study is to investigate the dosimetric differences between surface-guided radiation therapy (SGRT)-based and infrared-based deep inspiration breath-hold (DIBH) accelerated partial breast irradiation (APBI) for left-sided breast patients.

Methods: This retrospective study included twenty left-sided breast patients who underwent DIBH APBI using IMRT. Each patient's breathing trace acquired during CT simulation was imported into a programmable respiratory motion phantom to reproduce patient-specific breathing patterns and breath-hold motion during beam delivery. An SRS MapCheck detector was mounted on the motion platform to measure delivered dose. The SGRT system evaluated was AlignRT, and the infrared marker-based system was Real-Time Position Management (RPM). Clinical treatment plans were transferred to the phantom geometry and delivered twice per patient: once using RPM gating and once using AlignRT gating. Gamma analysis comparison was performed between the planned and measured dose distributions using clinical criteria to evaluate dosimetric agreement under the two gating techniques.

Results: Gamma analysis suggests that both gating systems demonstrate comparable performance during breath-hold delivery.

Conclusions: Under simulated patient-specific respiratory motion, RPM-gated delivery demonstrated dosimetric accuracy comparable to SGRT-based delivery with AlignRT. These results suggest that both motion management approaches provide similar dose delivery performance for DIBH APBI.

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INTRODUCTION

Deep inspiration breath hold (DIBH) has become a widely adopted technique in radiation therapy, particularly in the focus of Accelerated Partial Breast Irradiation (APBI). The technique serves a dual purpose of immobilization during the hold that allows for dosimetric accuracy to the target volume and a reduction in volume size by removing the margin of error from breathing, while also providing normal tissue dose protection such as to the heart and lungs by elevating the target volume and moving away the organs at risk.

However, the clinical benefit of DIBH is entirely dependent on the ability to reproduce the same breath-hold position accurately and consistently, both within a single fraction and across the full course of treatment. Variability in breath-hold depth, patient anatomy shift, or intrafraction motion can compromise target coverage and diminish the intended sparing of organs at risk, undermining the very purpose of the technique.

This is where robust position management systems become essential via means of beam delivery control during only specified target regions of the breath-hold. Real-time Position Management (RPM) through its breath-hold amplitude detection via infrared reflective marker and Surface-Guided Radiation Therapy (SGRT) through optical surface imaging to continuously map the visible patient body both provide continuous, non-invasive monitoring that improves setup accuracy, enhances intrafraction motion detection, and supports consistent breath-hold reproducibility. Their integration into DIBH workflows reduces reliance on additional imaging dose, increases patient safety, and helps ensure that the geometric and dosimetric advantages of breath-hold treatment are reliably achieved at every fraction.

METHODS AND MATERIALS

Respiratory trace lines of left-sided breast patients who underwent DIBH APBI using IMRT were acquired from the CT simulation and were imported into a programmable respiratory motion phantom to reproduce the recovered breathing traces simulating active patient breathing during delivery.

A Sun Nuclear SRS MapCheck detector was attached to the respiratory motion phantom platform to simulate the patient target motion, of which the original patient plans were transferred to the phantom geometry.

Both the SGRT-based AlignRT and infrared marker-based system RPM were used to control beam delivery. Each plan was delivered and fluence measured for each system's delivery of the patient plan.

Gamma Analysis was performed using the vendor specific software SNC Patient for the SRS MapCheck.

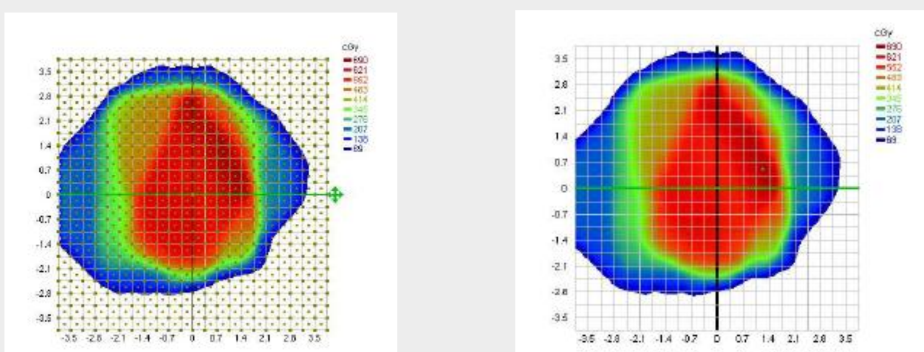

Figure 1. Example of measured (left) and planned (right) cumulative dose distribution

RESULTS

- Gamma Analysis of the measured fluences were recorded and a ratio of the pass rates of the SGRT-based AlignRT system was done to those of the RPM system.
- For the 20 data points, a mean of 2.57% difference was determined with a standard deviation of 5.03% and a range of up 12.82%.
- While the distribution shows lack of normal distribution, as shown by the p =0.0118 of the Shapiro-Wilk test, the non-parametric Wilcoxon signed-rank test results in p = 0.029 showing a non-noise difference between the systems.
- 14 of the cases demonstrated higher pass rate for the SGRT-based system.
- Relative analysis reveals comparable pass rate values to those of the Patient Specific Quality Assurance delivered prior to the patient's treatment when compared relatively using the typical Gamma Criterion of 2%, 2mm, and 10% threshold.

Table 1. Ratio of Gamma Pass Rate between SGRT and RPM

Test #	Ratio % Difference
C1	3.12
C2	8.84
C3	-0.86
C4	5.12
C5	4.44
C6	5.31
C7	5.44
C8	0.75
C9	-4.60
C10	4.60
C11	3.95
C12	2.86
C13	-2.33
C14	2.59
C15	8.89
C16	3.42
C17	5.17
C18	-0.18
C19	-12.82
C20	7.73

Figure 2. Quasar Modus Phantom setup with SRS MapCheck and RPM block

DISCUSSION

- The results demonstrate a promising comparison of the two patient position management systems with a 2.6% mean difference between gamma pass rates of the systems in favor of the SGRT system.
- The Statistical tests demonstrate that the difference is not by happenstance between the performance of the SGRT system in relation to that of the RPM.
- The relative fluence between the measured and calculated fluence demonstrated highly passing gamma analysis consisting of a range between 95% to 100%, revealing a well organized and consistent distribution of dose delivered when controlled by either of the Position Management systems.
- The SRS MapCheck was designed to be used and calibrated using the provided stereophan platform it is normally housed in. Due to the setup and size of the housing, it would make the detector incompatible with the motion phantom due to its weight and size. This provides a venue for further testing by follow up on a potential adapter that would allow the full system to be integrated with the motion phantom.

CONCLUSIONS

The importance of reproducibility and consistency when using Deep Inspiration breath-hold techniques cannot be more emphasized to ensure patient safety and dosimetric accuracy. Both systems represent a well-designed quality system to ensure that both dosimetric outcome and normal tissue toxicity are maintained and lowered, respectively, of which the test reveals a consistent non-happenstance outcome average improvement via the SGRT-based system over the RPM system yet both still useable.

Further testing with an adapted setup can further elucidate on the exact nature of the improvement the SGRT-based system can provide.

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