# Analysis of Varian RPM Reproducibility during deep inspiration breath-hold with AlignRT monitoring

**E. WRIGHT[1], K. BOTA[1], S. KARNAS[1,2], S. GAEDE[1,2,3]**

1. London Health Sciences Centre, London, ON, Canada
2. Department of Medical Biophysics, Western University, London, ON, Canada
3. Lawson Imaging, Lawson Health Sciences Centre, London, ON, Canada

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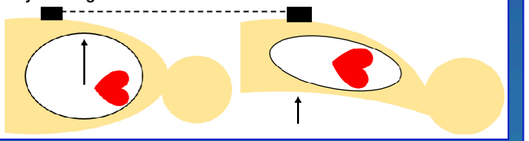
## INTRODUCTION

- Radiation therapy (RT) for left breast cancer causes cardiac perfusion defects in ~40% of patients[1] and is associated with increased cardiac mortality[2]
- Deep inspiration breath hold (DIBH) techniques have been shown to reduce cardiac dose[3]
- External marker based gating is based on the vertical position of a marker, which could be influenced both by breath-hold or intrafraction motion (e.g. arching the back)
- Lifting the marker into the gating window without moving the target away from the heart could have potentially serious implications for cardiac dose during DIBH RT (Figure 1)

**Figure 1: Same vertical marker position achieved by DIBH and by arching the back**



## AIM

- To compare the reproducibility of breast surface position during DIBH RT when breath-hold is guided by external marker based tracking versus surface-guided RT (SGRT)

## METHOD

- 9 left breast cancer patients were treated with whole breast tangents on a True Beam linac using a DIBH technique
  - Treatment was gated by the Real Time Position management (RPM) system (Varian Medical Systems, Palo Alto, USA) while simultaneously monitoring breast position with AlignRT (VisionRT, London, UK) in 6 patients
  - Treatment was gated by AlignRT in 3 patients
- RPM log files were synchronized with the corresponding portion of the AlignRT log file
- For each treatment fraction, inter-tangent difference in mean vertical position of RPM block and mean real-time delta values from AlignRT during beam-on time were determined
- Differences in breast surface position were compared between patients gated by RPM versus AlignRT
- Percentage of beam-on time where AlignRT parameters were within tolerance was also determined for 4 of the 6 patients gated by RPM
  - 2 patients were excluded because the AlignRT reference surface was not in the breath-hold position

## RESULTS

**Figure 2: Absolute inter-tangent differences in average surface position during beam-on time for all patients gated by RPM and AlignRT**

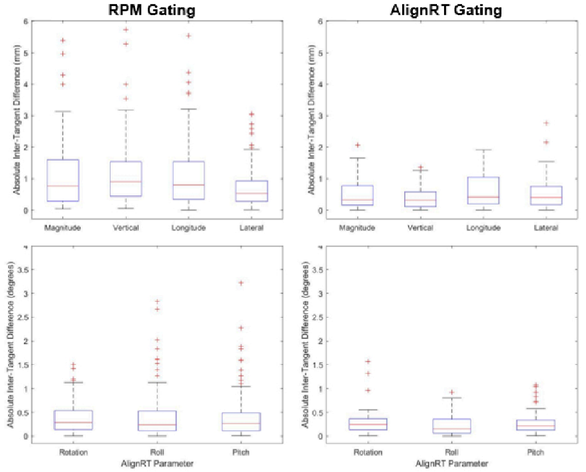



**Figure 3: Example of inter-tangent differences in breast position observed by AlignRT that were not evident with RPM**

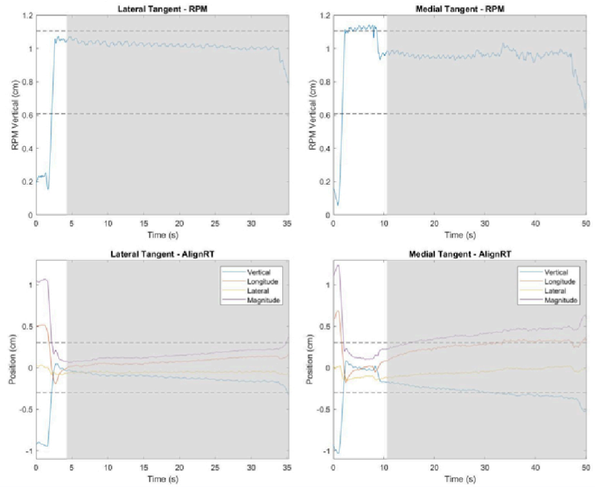



**Table 1: Absolute inter-tangent differences in average surface position during beam-on time for each patient**

| Patient | Gating | Fractions | Average Inter-Tangent Difference ± Standard Error (mm/degrees) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | RPM | Magnitude | Vertical | Longitude | Lateral | Rotation | Roll | Pitch |
| 1 | RPM | 13 | 0.60 | 0.64 | 0.63 | 0.71 | 0.28 | 0.22 | 0.14 | 0.19 |
| 2 | RPM | 14 | 0.97 | 0.83 | 0.99 | 0.92 | 0.54 | 0.26 | 0.21 | 0.26 |
| 3 | RPM | 13 | 0.63 | 1.15 | 0.96 | 1.02 | 0.93 | 0.53 | 0.82 | 0.58 |
| 4 | RPM | 14 | 0.96 | 1.04 | 1.14 | 1.17 | 1.03 | 0.47 | 0.42 | 0.27 |
| 5 | RPM | 10 | 0.80 | 1.68 | 1.92 | 1.81 | 0.74 | 0.35 | 0.51 | 0.97 |
| 6 | RPM | 10 | 1.07 | 1.20 | 1.01 | 0.98 | 0.45 | 0.49 | 0.21 | 0.22 |
| 7 | AlignRT | 16 | - | 0.31 | 0.22 | 0.33 | 0.34 | 0.21 | 0.20 | 0.16 |
| 8 | AlignRT | 15 | - | 0.49 | 0.62 | 0.81 | 0.54 | 0.39 | 0.36 | 0.35 |
| 9 | AlignRT | 15 | - | 0.64 | 0.48 | 0.82 | 0.67 | 0.31 | 0.18 | 0.35 |

**Figure 2 (left):** Absolute inter-tangent difference in average surface positions during beam-on time in patients gated by RPM (n = 6), and AlignRT (n = 3). Red lines indicate median, blue lines indicate 25th and 75th quartile, black lines indicate range excluding outliers (red crosses), which were points outside 2.7 times the standard deviation. Gating with AlignRT decreased inter-tangent differences in vertical, longitudinal, and lateral breast position by 64%, 44%, and 27% respectively, and decreased differences in breast surface rotation, roll, and pitch by 29%, 45%, and 35% respectively

**Table 2: Percentage of total beam-on time where AlignRT parameters were in-tolerance in treatments gated by RPM**

| Patient | Total Beam-on Time in Tolerance (s) | Total Beam-on Time (s) | % of Total Beam-on Time in Tolerance |
|---|---|---|---|
| 1 | 663.6 | 782.4 | 84.8 |
| 2 | 974.0 | 1174.2 | 82.9 |
| 3 | 503.7 | 688.7 | 73.1 |
| 4 | 802.4 | 998.6 | 80.3 |

**Table 2 (above):** The percentage of total beam-on time, over all treatment fractions, where AlignRT parameters were within tolerance (± 3mm/3°), in four patients where treatment was gated by RPM. Two patients were excluded from this analysis because the reference surface used for AlignRT monitoring was not in the breath-hold position

**Figure 3 (left):** RPM vertical position over the course of beam delivery for lateral (left) and medial (right) tangents is shown in the top row, and AlignRT parameters over the course of beam delivery are shown in the bottom row. Dashed lines indicate the RPM gating window and the ± 3mm window where AlignRT parameters are in-tolerance. The average RPM marker block vertical positions during beam-on for the lateral and medial tangents were 10.1mm and 9.5mm respectively. Despite minimal change in RPM block height (0.6mm), differences in average AlignRT magnitude, vertical, and longitude during beam-on time were 2.5mm, 1.7mm, and 1.9mm respectively, suggesting the block may be driven into the gating window by intrafraction motion instead of breathing

## DISCUSSION AND CONCLUSIONS

- Gating with AlignRT resulted in less intra-fraction variability in breast position compared to gating with external marker based methods (0.5mm vs. 1.1mm)
- This agrees with previous studies showing less inter- and intra-fraction variability in breast surface position using SGRT vs RPM and spirometry[4-7]

| DIBH Control | Surface Variability (mm) | Inter-/intra-fraction |
|---|---|---|
| RPM[4] | 5.9 | Inter-fraction variability |
| Spirometry[5] | 2.8 | Intra-fraction variability |
| SGRT[6] | 1.6 | Intra-fraction variability |
| SGRT[7] | 0.3 | Intra-fraction variability |
| | 1.3 | Inter-fraction variability |

- AlignRT was out of tolerance 15% to 27% of the total beam-on time where the RPM marker block was in the gating window
- Most common reason was drift in the longitude and vertical parameters over course of beam delivery (Figure 3)
  - Patients unable to maintain breath-hold for the entire time may be keeping the marker block within the gating window by arching their back
- We recommend monitoring of breast surface position in all 6 dimensions with surface-guided RT when DIBH techniques are used

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## CONTACT INFORMATION

Eric Wright, PhD – Email: Eric.Wright@lhsc.on.ca