Intrafraction Motion Monitoring to Determine PTV Margins in Early Stage Breast Cancer Patients Receiving Neoadjuvant Partial Breast SABR

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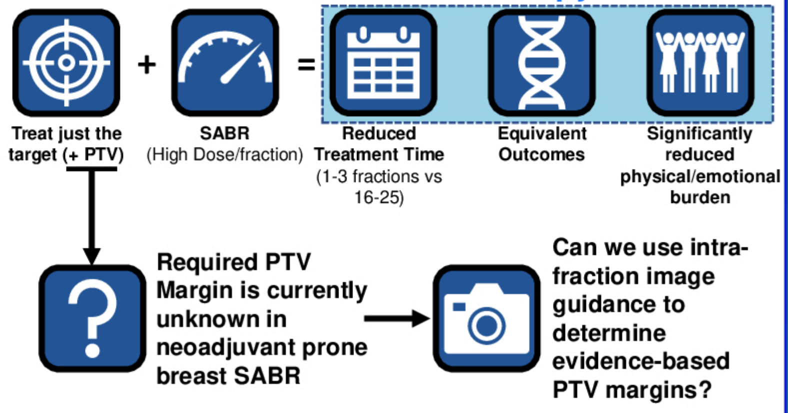
INTRODUCTION

PRE-SURGERY (neoadjuvant) PARTIAL BREAST SABR VS. Whole Breast Radiotherapy



AIM

- Use **intra-fraction image guidance** to retrospectively quantify the **degree of motion and van Herk[1] PTV margins for treatment of** early stage breast cancer patients in the **prone position** using 21 Gy / 1 fraction or 30 Gy / 3 fraction stereotactic ablative radiotherapy (SABR) before surgery
- Determine if any **patient specific features** lead to difficult treatments using **statistical modelling (mixed model regression)**

METHODS

- Patients were treated prone (Aktina Medical©) with a PTV margin of 5mm from the CTV[2]
- A fiducial (HydroMark©, Mammotome) was placed adjacent to or within the tumour
- **Intra-fraction motion was quantified using 2 methods**:
  - 1) The difference in clip position in cone-beam CTs acquired before and after treatment (Method 1)
  - 2) Using the triggered kV images acquired during treatment delivery and a 2D-3D motion estimation algorithm[3] with automatic clip finding (Method 2)
- Features related to the patient and their treatment were collected and a mixed effects linear model was applied using these features as factors and the total Euclidean distance deviation of the clip from the start of treatment as the dependant variable was calculated
  - The effects were plotted to visualize the strength of the correlation

RESULTS

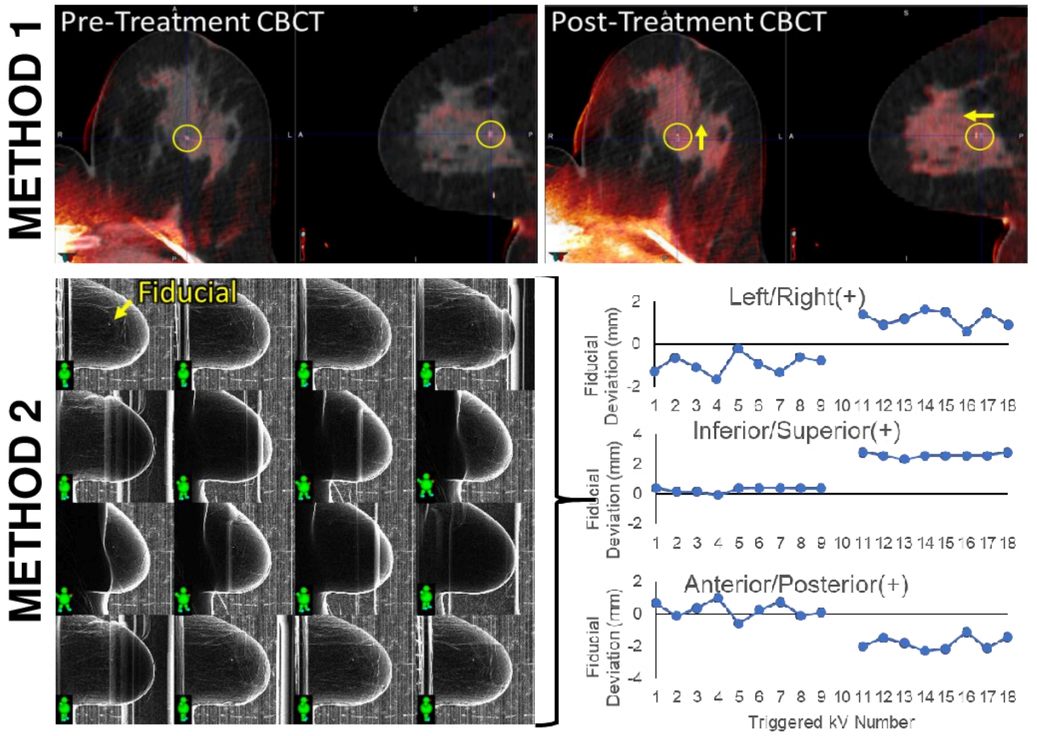


Figure 1 – Representative patients from Method 1 (top row) and method 2 (bottom row). In method 1, the pre- and post-treatment CBCT are used to determine the total intrafraction movement of the fiducial by calculating the difference pre- to post-treatment in each direction. In method 2, the fiducial is located on the 2D triggered kV images acquired during treatment (bottom row, left) and then the 3D position reconstructed using a maximum likelihood estimation method (bottom row, right). From this we can recover the intra-fraction mean and standard deviation of the fiducial error. *Note that the kV images in method 2 have a gradient filter applied for better visualization of the fiducial.*

Table 1 – Summary information of the mean magnitude (± standard deviation (STD)) as well as components of the PTV van Herk margin recipe and the PTV margin estimations for both the single and three fraction groups. While the margins used in the current study (5mm) were well above the mean magnitude of motion, the PTV margin estimates suggest that they should be larger for the L/R and A/P directions Σ = systematic error in target position , σ_f = intra-fraction (random) error in target position, σ = inter-fraction (random) error.

	Left/Right	Inferior/Superior	Anterior/Posterior
Mean Magnitude of Motion (± STD) (mm)	1.5 ± 1.3	1.0 ± 0.9	1.8 ± 1.4
Σ (mm)	1.7	1.3	1.8
σ_f (mm)	1.4	0.4	1.0
PTV (1fx) (mm)	**5.3**	**3.6**	**5.2**
σ	1.7	1.1	1.4
PTV (3fx) (mm)	**5.9**	**4.2**	**5.7**

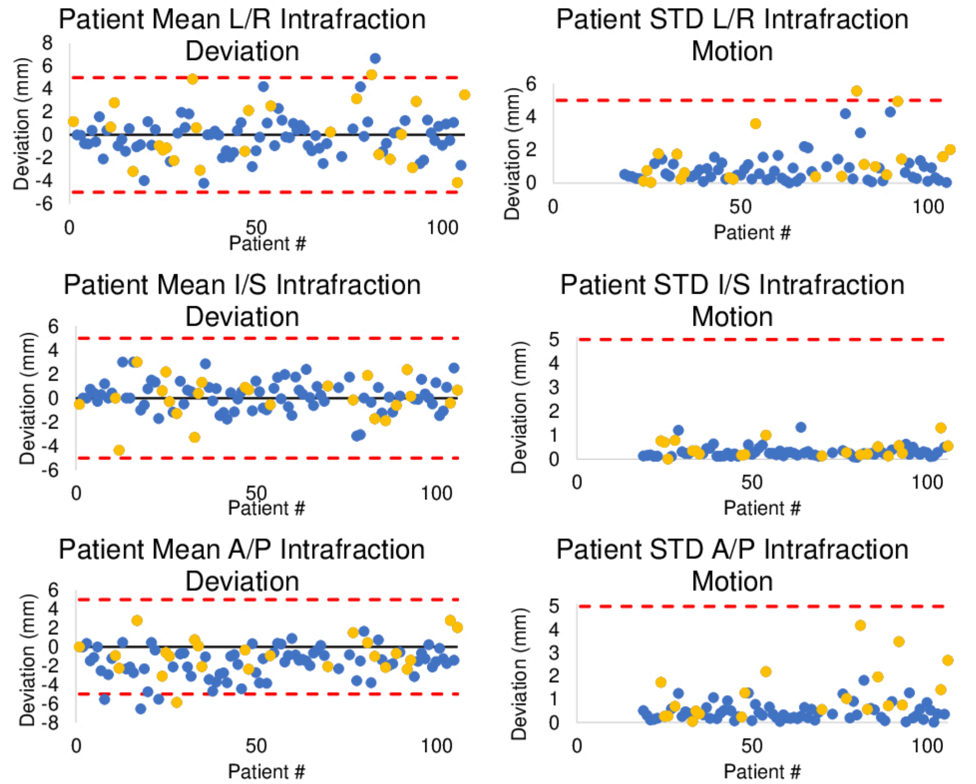


Figure 2 – Mean intra-fraction deviation (left column) and intra-fraction fiducial position standard deviation (right column) for each patient and each direction. Yellow markers indicate the patient had a difficult setup or treatment interruption. Red dashed lines indicate the PTV expansion margin. Concerning the mean intra-fraction deviation (left column), the L/R and I/S was distributed in either direction whereas A/P motion was predominately anterior, which is due to patient relaxation causing a descent into the prone breast board.

Patient Features (Predictors)	Significance (p-value)
Laterality (L/R)	NS (0.899)
Age	NS (0.807)
Volume	NS (0.428)
Fibro ratio*	NS (0.137)
Treatment Length	NS (0.081)
PTV-centroid to Ipsilateral Breast centroid distance	NS (0.521)
Couch shift magnitude	NS (0.431)

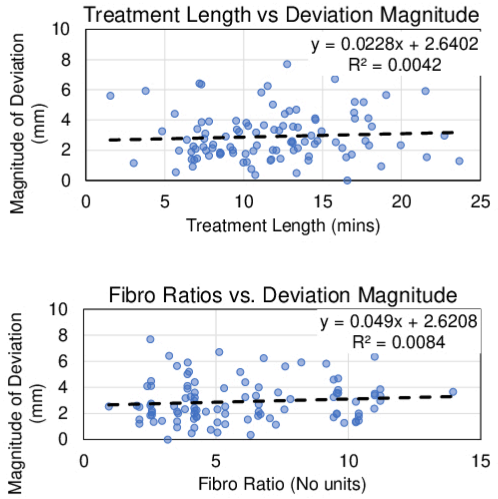


Figure 3 – Summary information of the mixed model fit to determine if patient features can predict the degree of patient motion (table on left) and a selection of the two features that had the highest effect (plots on right). It is clear that, while treatment length was approaching significance, the effect was very small and is likely not clinically relevant.

*The Fibro ratio is the ratio of the fibroglandular[4] tissue volume to the breast volume on the ipsilateral side.

DISCUSSION/CONCLUSIONS

- Other studies with a similar treatment setup (prone, SABR) have used various PTV margins varying from 2-5mm[5]

Table 2 – Comparison of present data to previous motion monitoring studies. Note that comparison is made difficult due to the fact that most studies are performed supine.

			Magnitude of Measured Motion		
Study	Position	Tracking Method	LR	IS	AP
Acharya *et al*[6]	Supine	Cavity in MRI-IGRT	-	0.6 ± 0.3 mm	0.6 ± 0.4 mm
Reitz *et al.*[7]	Supine	Catalyst Tracking	0.08 ± 0.65 mm	0.09 ± 0.81	0.39 ± 0.98
Zhen *et al.*[8]	Supine	Cyberknife	1.0 ± 0.3	1.1 ± 0.7	1.3 ±0.6
This Study	**Prone**	**CBCT / Triggered kV**	**1.5 ± 1.3**	**1.0 ± 0.9**	**1.8 ± 1.4**

- Part-way through, we introduced a lateral kV image to correct for patient anterior motion. This resulted in a reduction in the AP motion from 1.8 ± 1.4 mm (table 1) to 1.5 ± 1.1 mm (figure 2, bottom left, patient 75 to end). Then, the PTV margins would be 4.4 and 4.9 for 21Gy/1fx and 30Gy/3fx
- **Our data suggests that a 5mm is sufficient to cover the CTV for 90% of patients so long as a lateral kV is used to adjust for patient anterior motion in prone position**
- We plan to investigate the use of techniques to reduce motion
  - A 3D printed, patient-specific, immobilization device
  - Stricter motion thresholds for therapist intervention

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