SGRT for Breast Radiotherapy including Deep Inspiration Breath-hold Techniques

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Disclosures

- I receive royalties from the University of Chicago for software licensed for computer aided detection of breast cancer.
- I am Chair of TG-302: Surface Image Guided RT.
- I receive grants from Varian for research unrelated to this presentation.

Outline

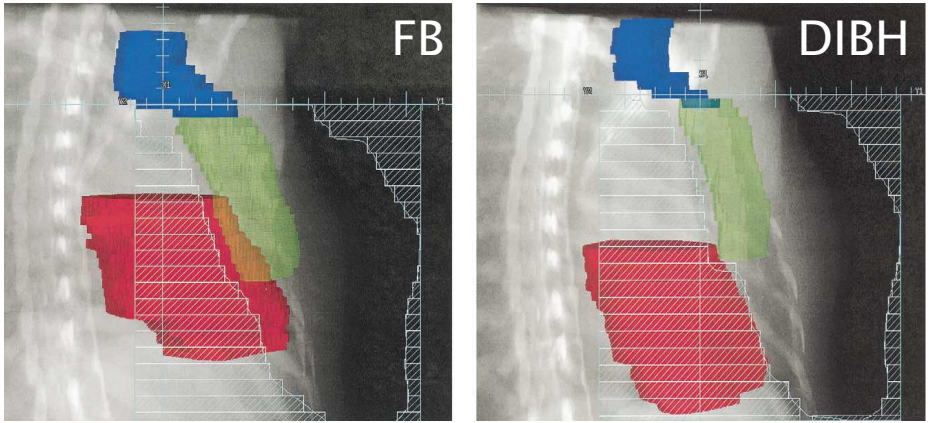
1. Overview of SGRT for DIBH in breast cancer
2. Workflow issues to consider when implementing SGRT for DIBH
3. Common pitfalls (& potential solutions) when using SGRT for DIBH treatments of breast cancer

1. Overview of SGRT for DIBH

- DIBH Techniques

Advantages of DIBH

- Freeze organ/tumor motion
- Separate heart from target (breast, IMN)
- Increase total lung volume



Remouchamps et al, *IJROBP*, 55(2): 392–406, 2003.

Active Breathing Control (ABC) with Spirometer at William Beaumont

- Largest U.S. institutional experience:
  - 87 patients with ≤T2 disease
  - 50% treated with simple tangents only (FIF)
  - Median dose of 46Gy + 16Gy boost
- Compared to free-breathing (FB), moderate DIBH significantly *decreased*:
  - Mean heart dose (4.23Gy vs. 2.54Gy)
  - Mean left lung dose (9.08Gy vs. 7.86Gy)
  - All dosimetric parameters (V5, V10, V15, V20) for lung/heart

Swanson et al, *Am J Clin Oncol.* ,36(1): 24–30, 2013.

Voluntary Breath Hold vs. ABC

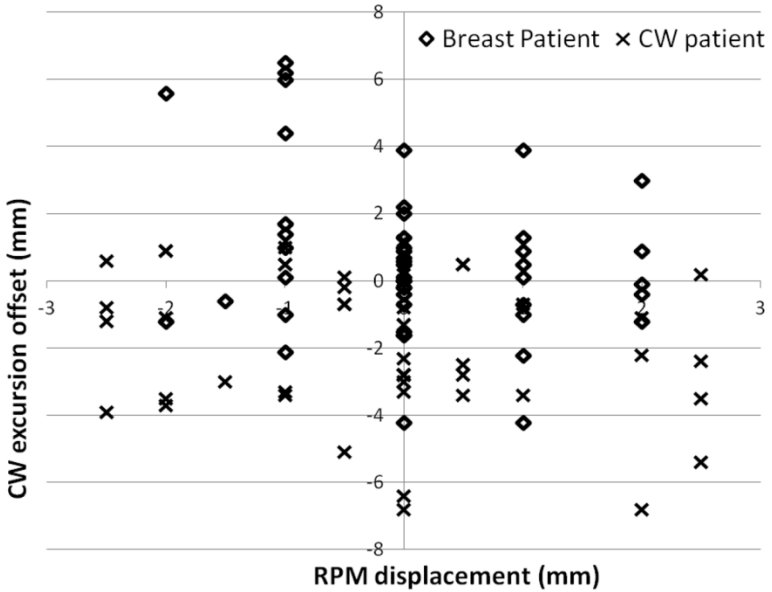
- 23 patients receiving 40 Gy in 15 fractions:
  - Randomized to v_DIBH or ABC_DIBH for 7 fractions & vice versa
  - Daily portal imaging & CBCT for 6 fractions
- No significant Δ: setup errors, normal tissue doses
- *Patients & therapists significantly preferred v_DIBH!*

Free breathing v_DIBH ABC_DIBH

Bartlett et al, *Radiother Oncol*, 108 :242–247, 2013.

Real-Time Position Management (RPM) for voluntary Breath Hold

- No correlation between chestwall excursion & RPM displacement (Rong et al)
- IR surface markers to assess RPM for BH determined that target positioning accuracy was degraded because of inter-fraction baseline shifts which could be corrected using surface data (Fassi et al)



Rong et al, *PLOS ONE*, 9(5), 2014.
Fassi et al, JACMP, 19:435-43, 2018.

SGRT vs Spirometric Signal

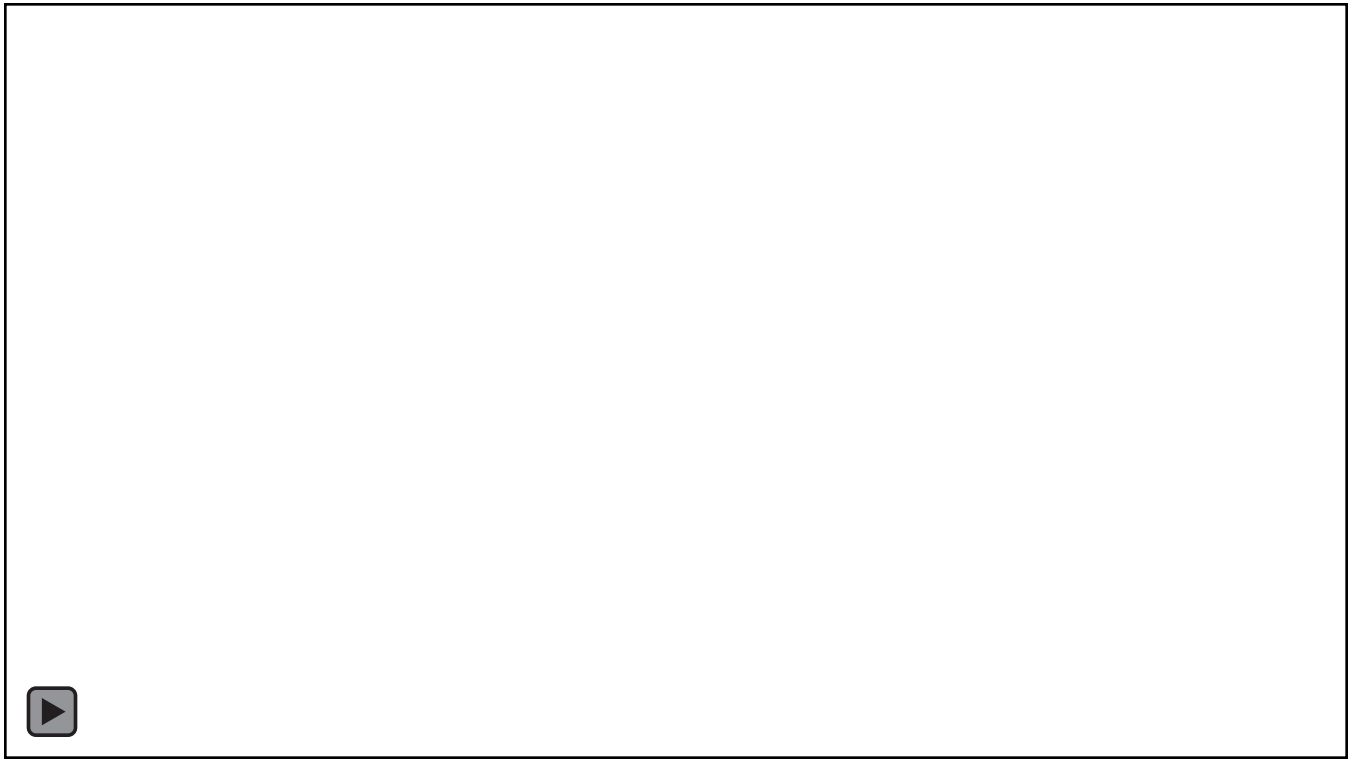
- A strong relationship was found for most patients using linear regression between spirometer-derived ventilatory signal & SGRT
- "Drift [of spirometer-derived ventilatory signal] was probably due to an inadequate seal being formed by the patient's lips around the spirometer mouthpiece allowing air to escape during breathing"
- SGRT could detect thoracic and abdominal volume changes during different modes of breathing (without baseline drift)

Table 4
The mean differential volume changes of the thoracic and abdominal regions of interest during different modes of breathing.

Bounding box	Breathing mode				
	Normal	Abdominal	Thoracic	Deep	Shallow
Global	1	1.47	1.18	1.76	0.87
Thoracic	1	1.30	1.67	2.30	0.82
Abdominal	1	1.69	1.03	1.52	0.91

Hughes et al, *Radiotherapy and Oncology* 91:336–341, 2009.

WBRT DIBH: INTRA-FRACTION MONITORING



2. Workflow Issues

- Patient Selection

Patient Selection for voluntary DIBH

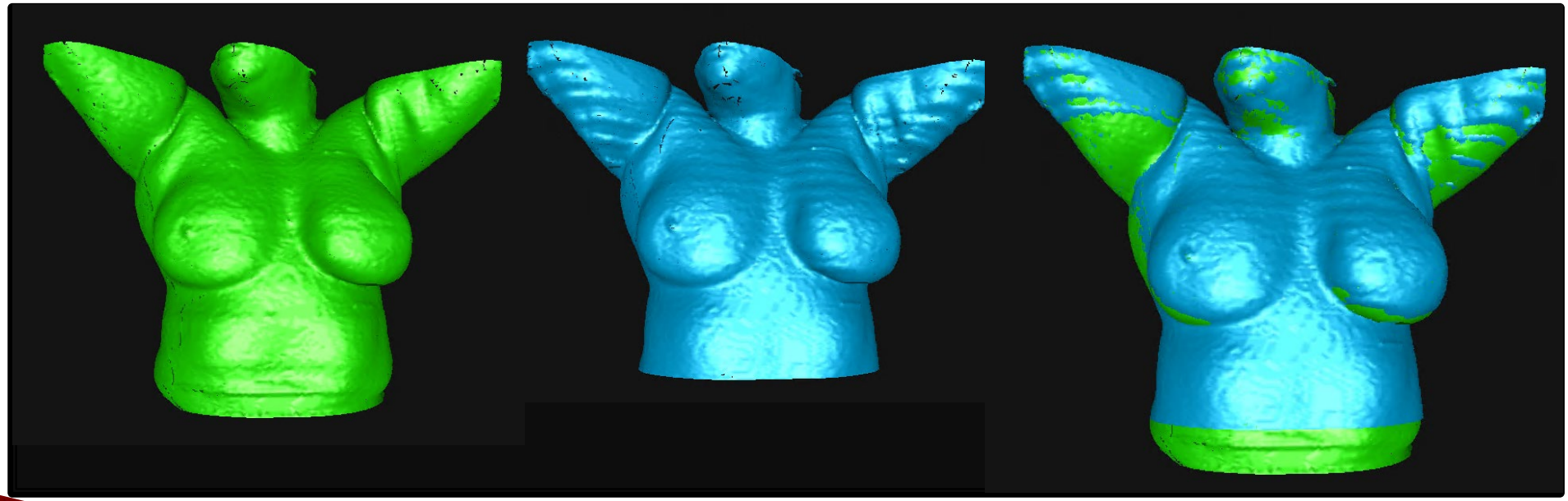
- Compliance
- Reproducibility of BH
- Breast size or pendulous shape
- Dosimetric threshold?

2. Workflow Issues

- CT simulation

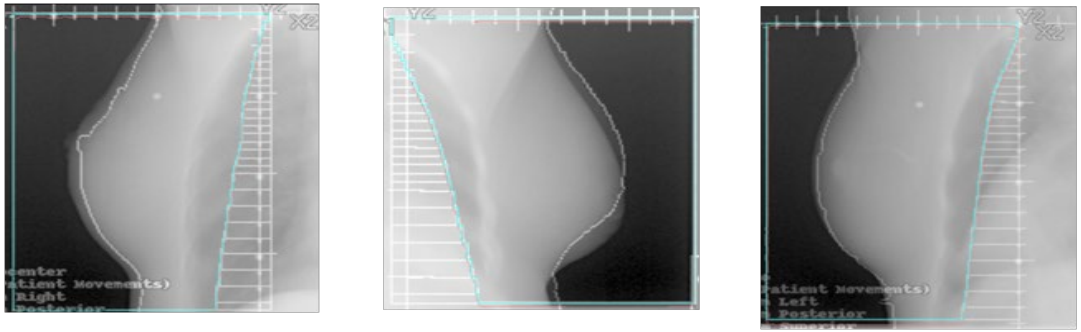
CT Simulation: Acquire FB & DIBH Scans → DICOM Surfaces

FB DIBH FB & DIBH



CT Simulation: Immobilization

- Good immobilization is important to ensure reproducible position of surface relative to bony anatomy
- Passive immobilization with tattoo-less is possible with SGRT

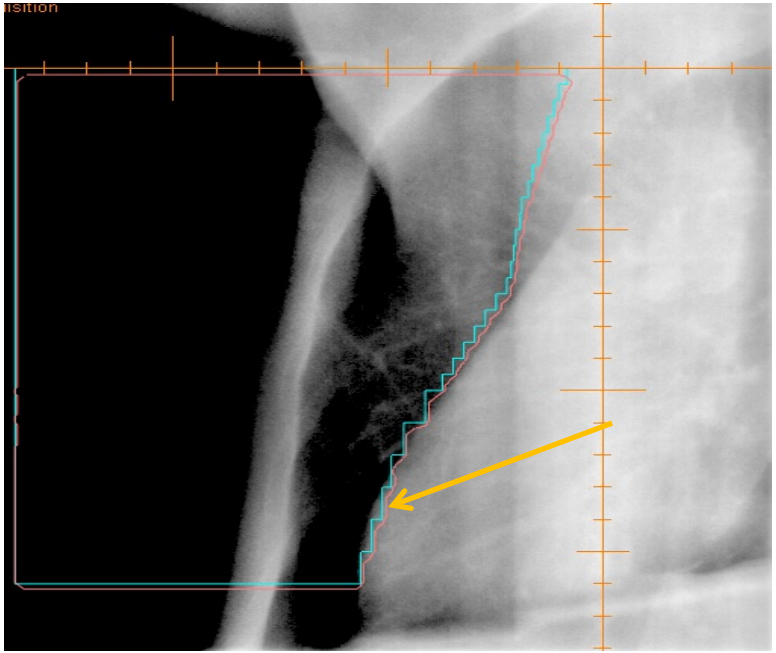


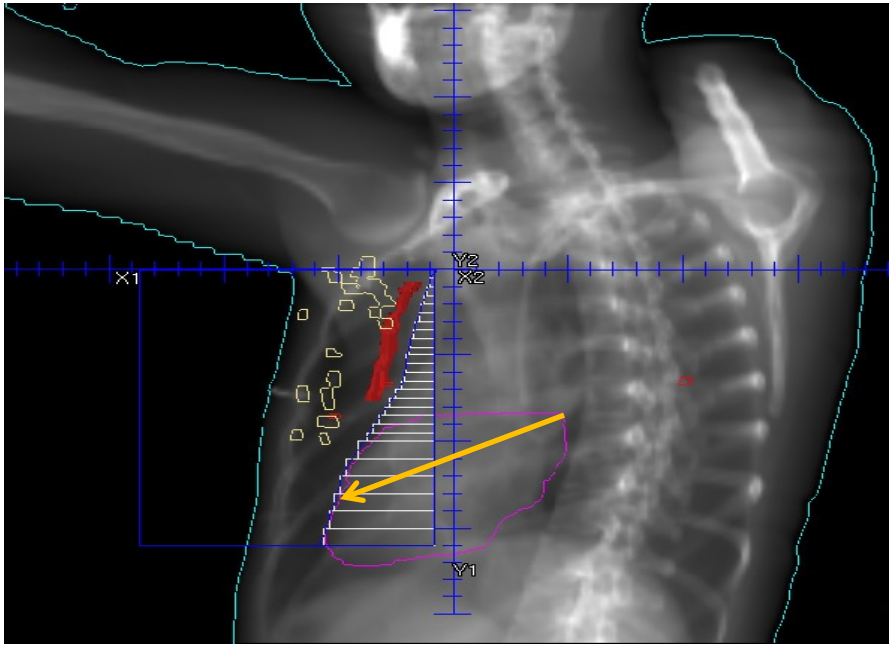
Padilla et al, JACMP 15: 4921, 2014.

2. Workflow Issues

- Verification of Heart Position

Verification of Heart Position: MV portal





Mean heart dose reduced from 4.8Gy (FB) to 1.2Gy (vDIBH)

2. Workflow Issues

- Bolus/Wedges/Mono-Isocenter/VMAT

Mono-Isocenter for Field Matching

- SGRT accuracy is better at isocenter (Wiersma et al 2013), which coincides with the matchline for plans in which tangential and supraclavicular fields have a common isocenter
- Kügele et al showed that DIBH isocenter reproducibility with SGRT was better for patients with tangential and supraclavicular fields compared to those with tangential fields only, possibly due to the isocenter placement at the matchline rather than in deformable breast tissue
- Xiao et al found significantly smaller setup errors in CC direction for 3-field vs 2-field DIBH treatments

Kügele et al, *JACMP*, 19(1):25-38, 2017.
Xiao, et al, *JACMP*, 19(4):205-213, 2018.

2. Workflow of SGRT for DIBH

- Summary

DIBH Workflow

CT Simulation:
- Create SGRT-friendly immobilization
- Acquire scans at FB and vDIBH

Planning:
- Create accurate body contours (DICOM)
- Export plan and body contours to SGRT system

Prepare data in SGRT system:
- Import plan and body contours
- Select ROIs and settings including thresholds

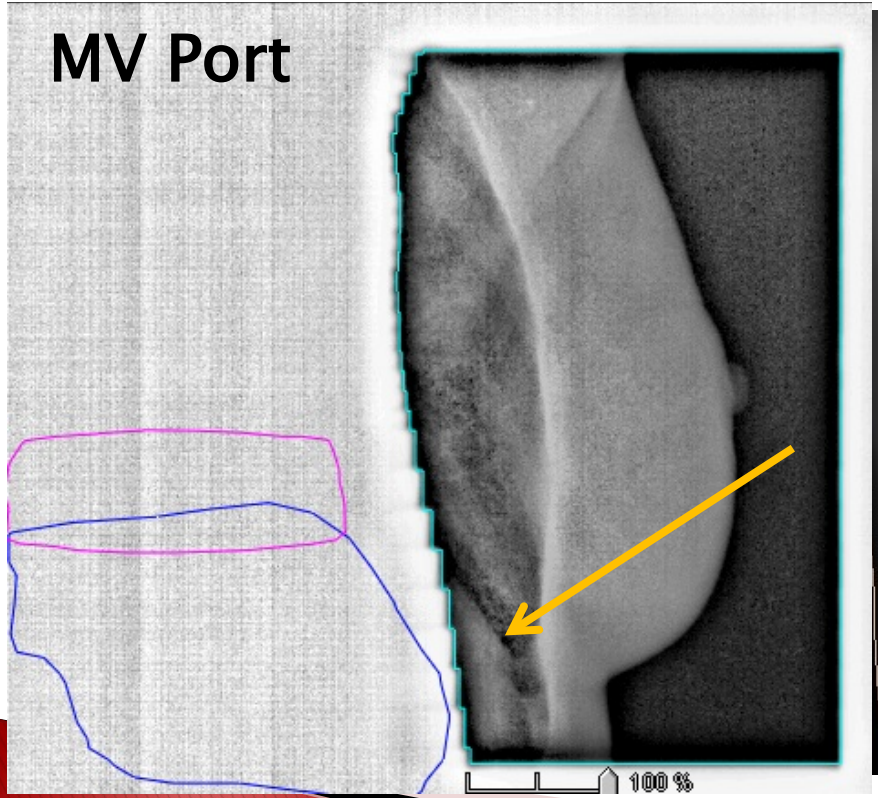
Positioning for Treatment:
- Initial positioning with SGRT at FB
- Fine-tune positioning with SGRT at vDIBH
- X-ray based target localization (e.g., kV/MV ports) to confirm vDIBH position at least once per week and for troubleshooting as needed

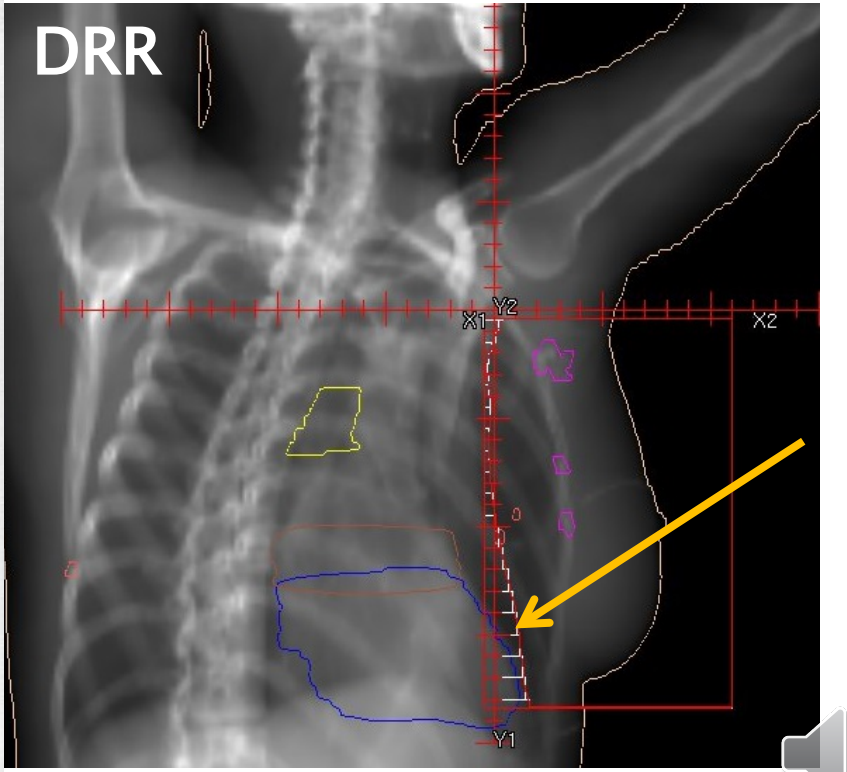
Treatment:
- SGRT monitoring of DICOM vDIBH surface
- If motion exceeds tolerance, coach patient to vDIBH
- If motion continues to exceed tolerance, return to “Positioning for Treatment”

3. Common Pitfalls

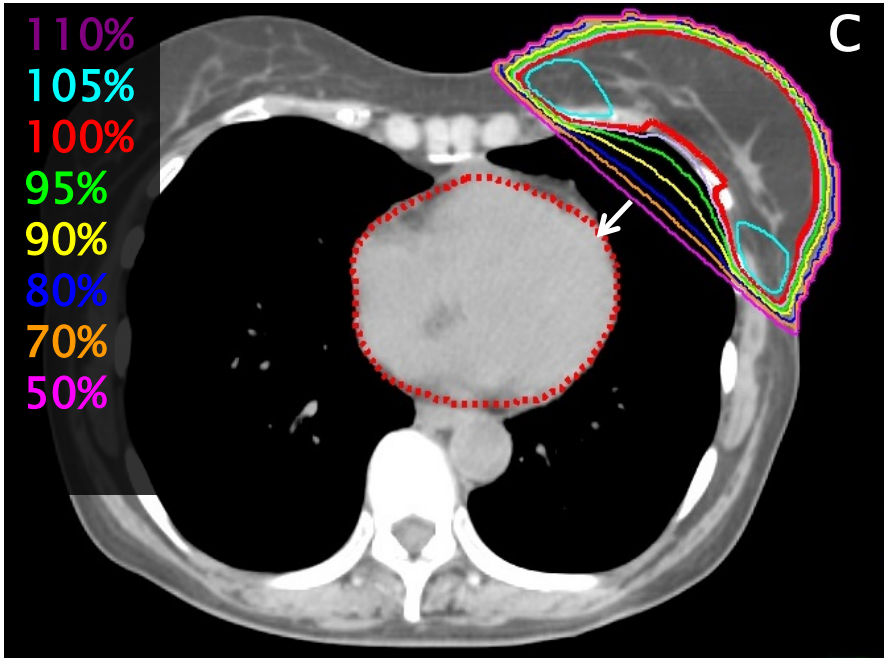
- Patient Changes:
  Breathhold Pattern

Identifying Changes in Breathhold Pattern

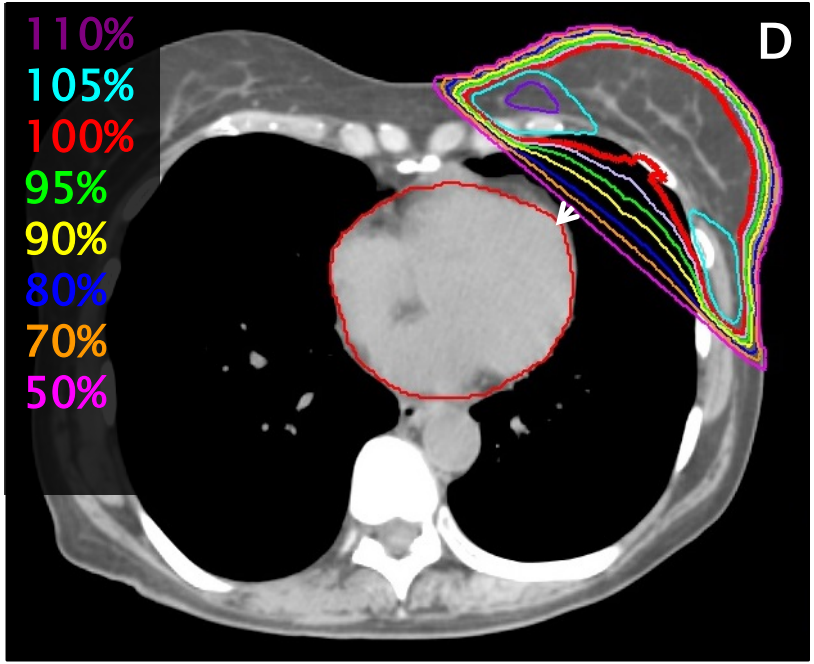




Identifying Changes in Breathhold Pattern

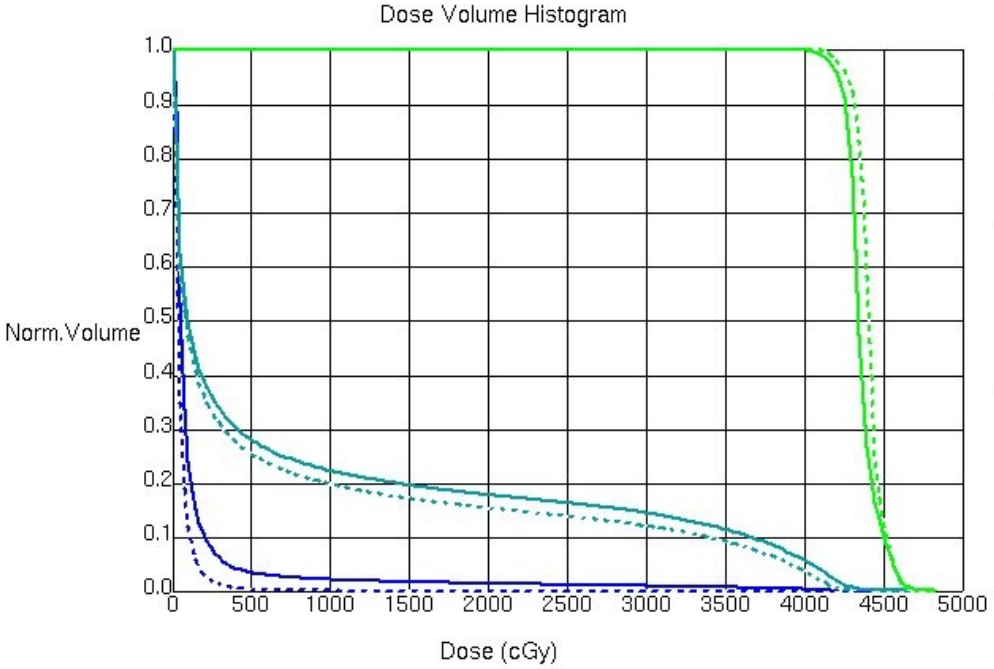


Planning CT DIBH



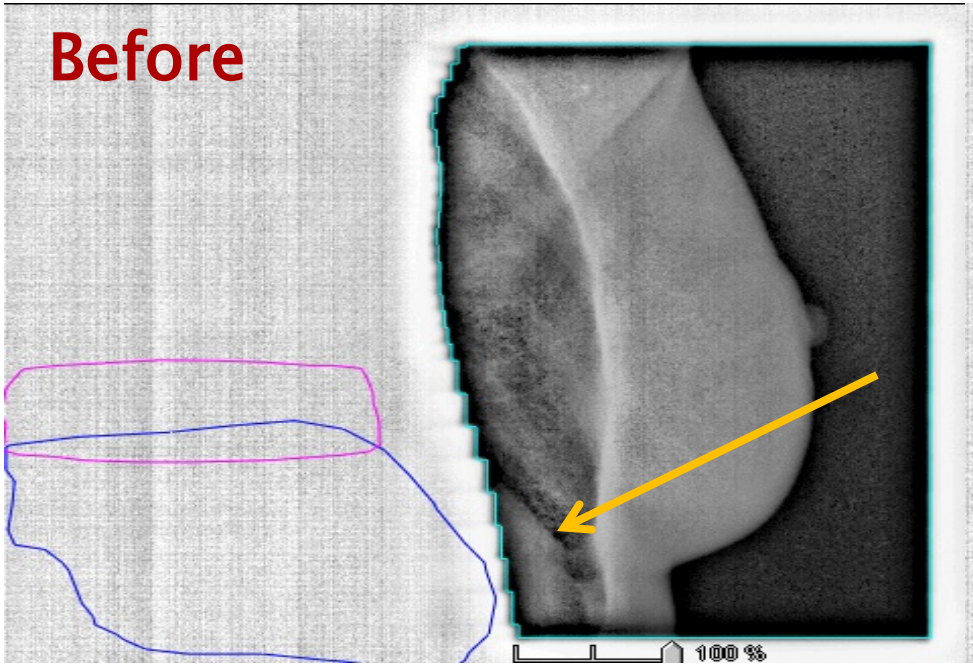
Repeat CT DIBH2

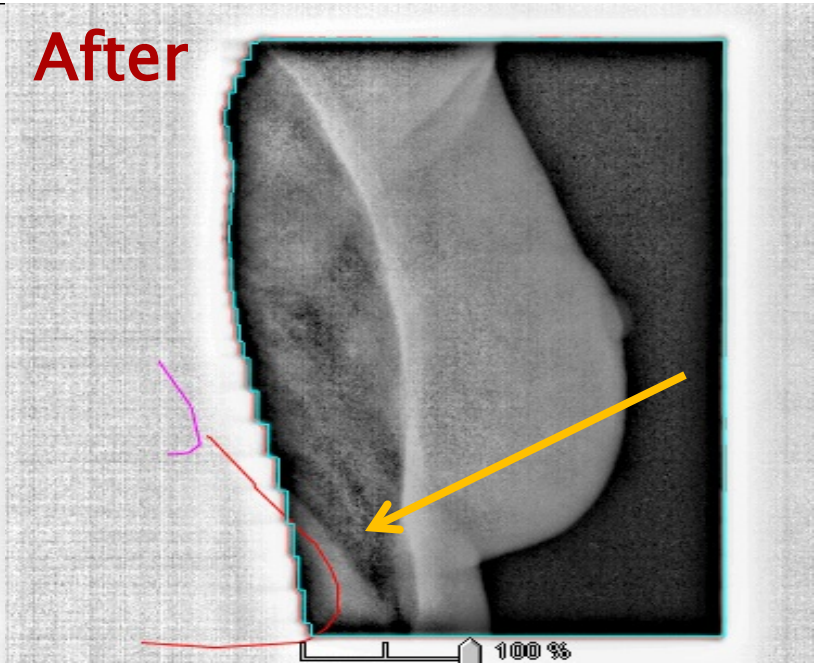
Identifying Changes in Breathhold Pattern



	CT1	CT2	FB
Mean Heart Dose (Gy)	0.5	1.4	2.7
Lung V20Gy	15%	17.7%	23%

MV Ports Pre & Post Re-simulation





Potential Solutions

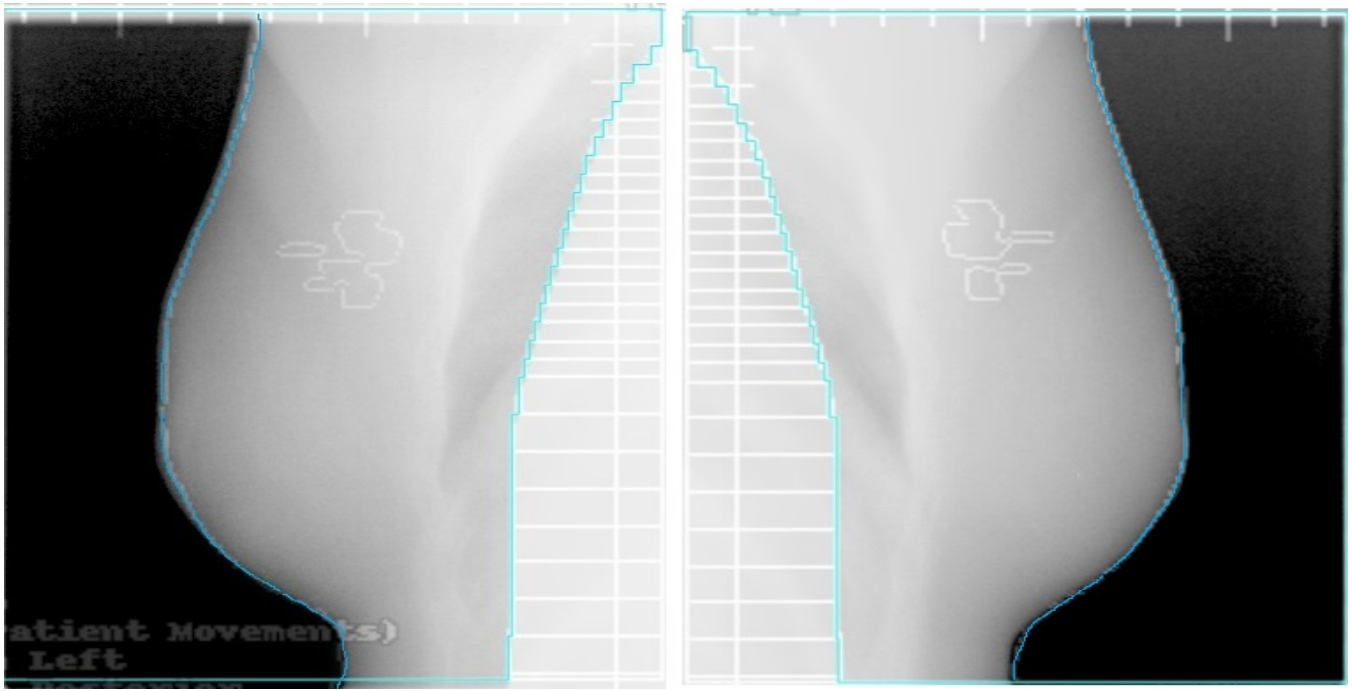
- Verify with internal x-ray imaging
- Adapt the plan as necessary
- Understand that variability exists!

3. Common Pitfalls

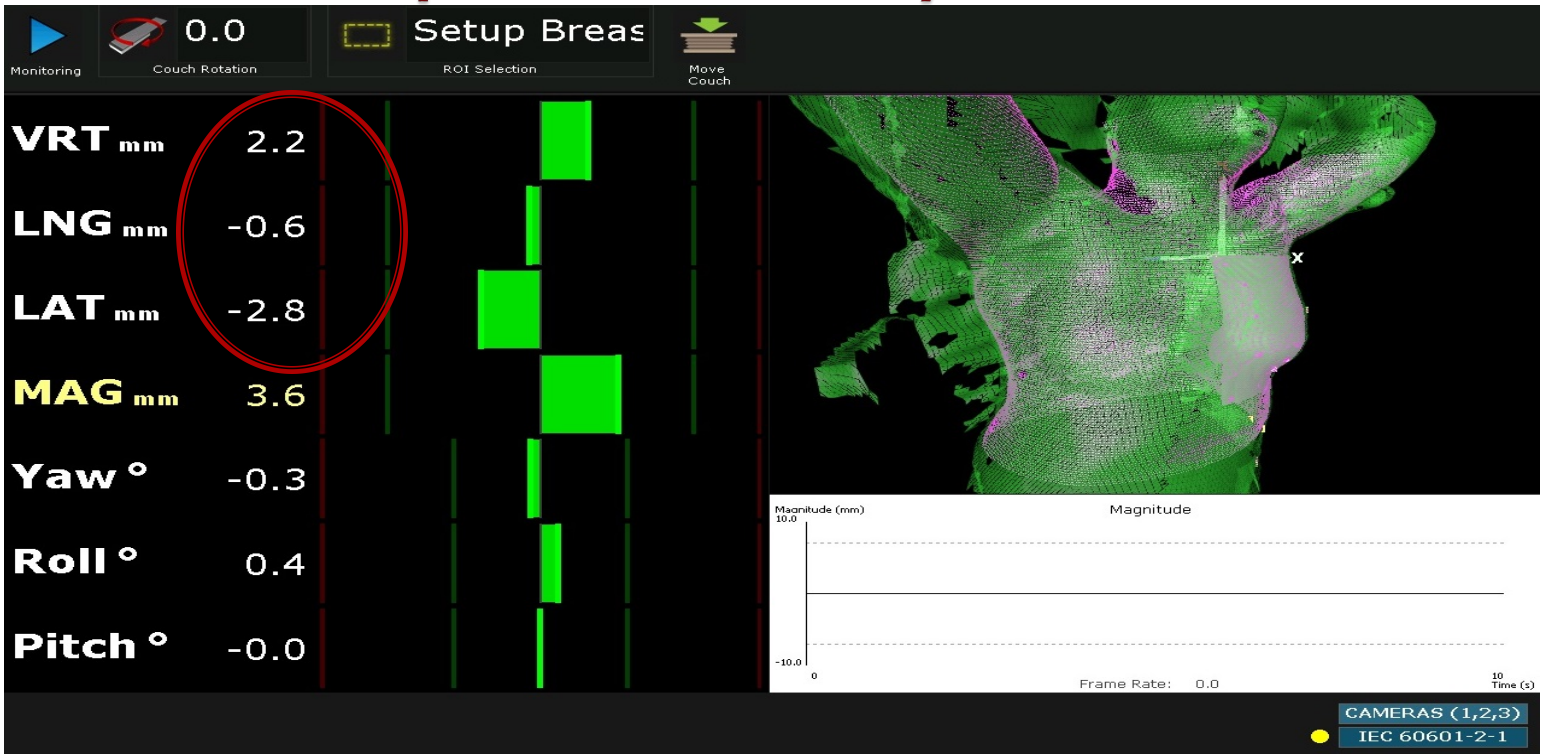
- Patient Changes: Anatomic Changes

WBRT Example:
First Day Orthogonal kV Films

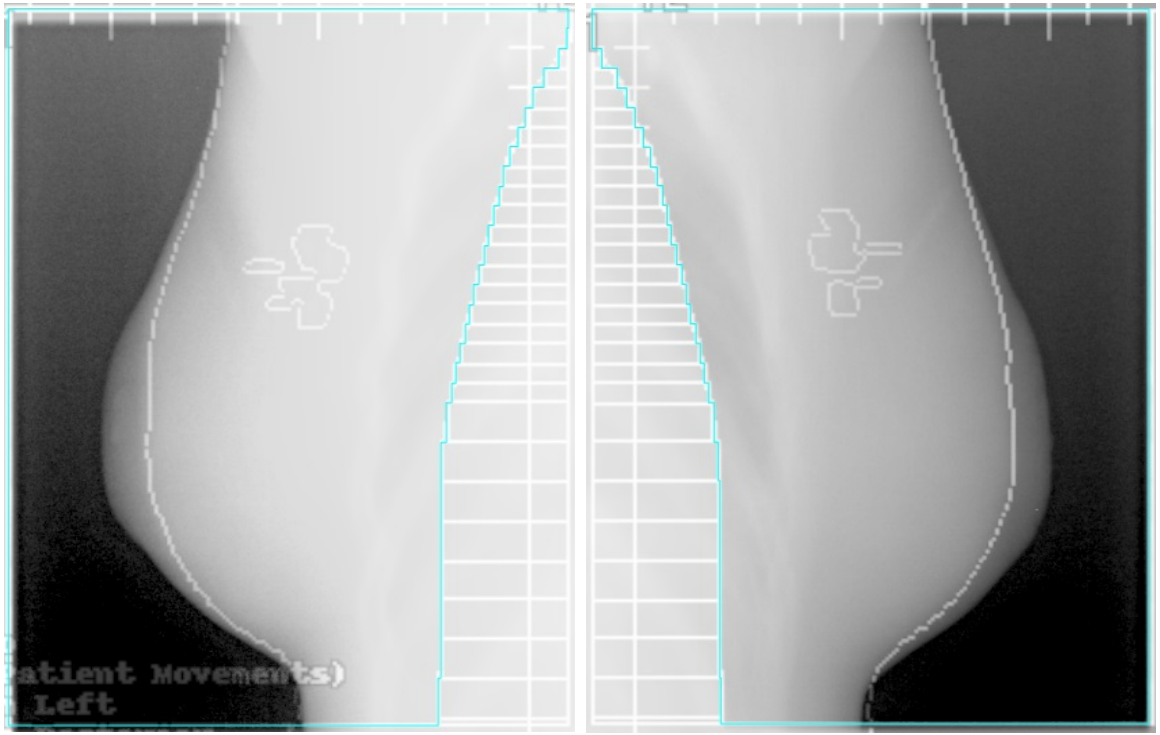
WBRT Example:
First Day Tangent MV Films



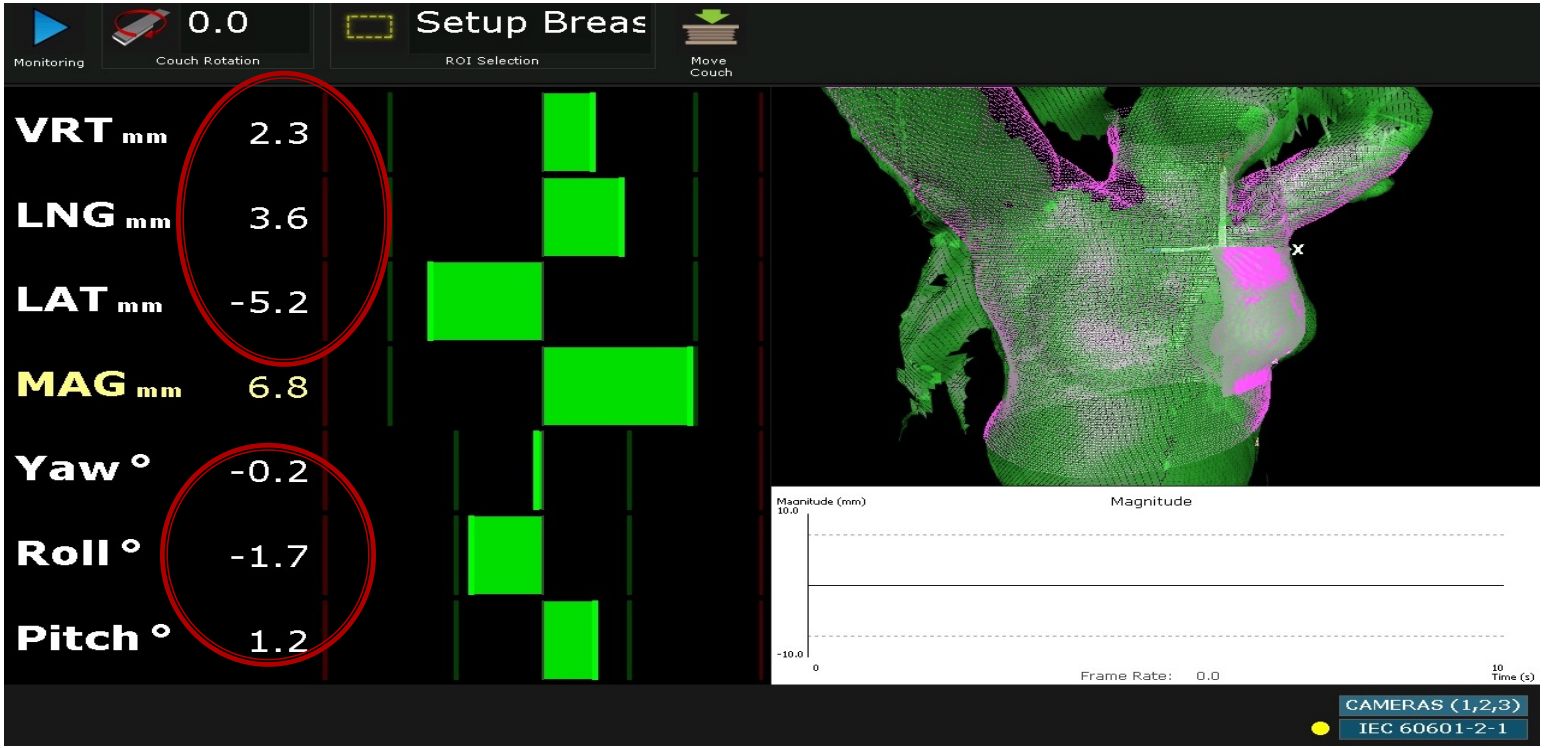
WBRT Example: First Day ‘Breast’ ROI



WBRT Example:
24th Treatment Tangent Films



WBRT Example: 24th Fraction ‘Breast’ ROI



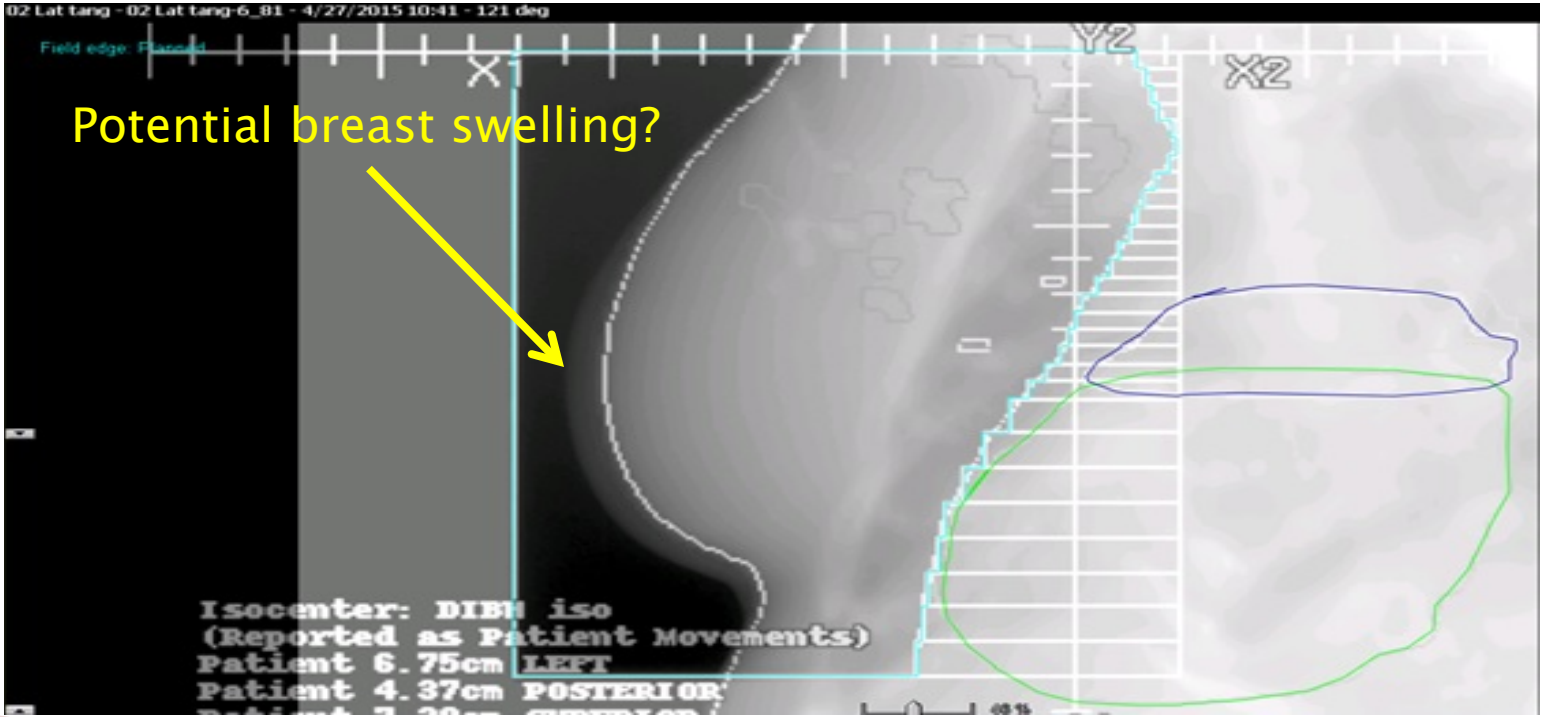
Potential Solutions

- Clinical team to investigate

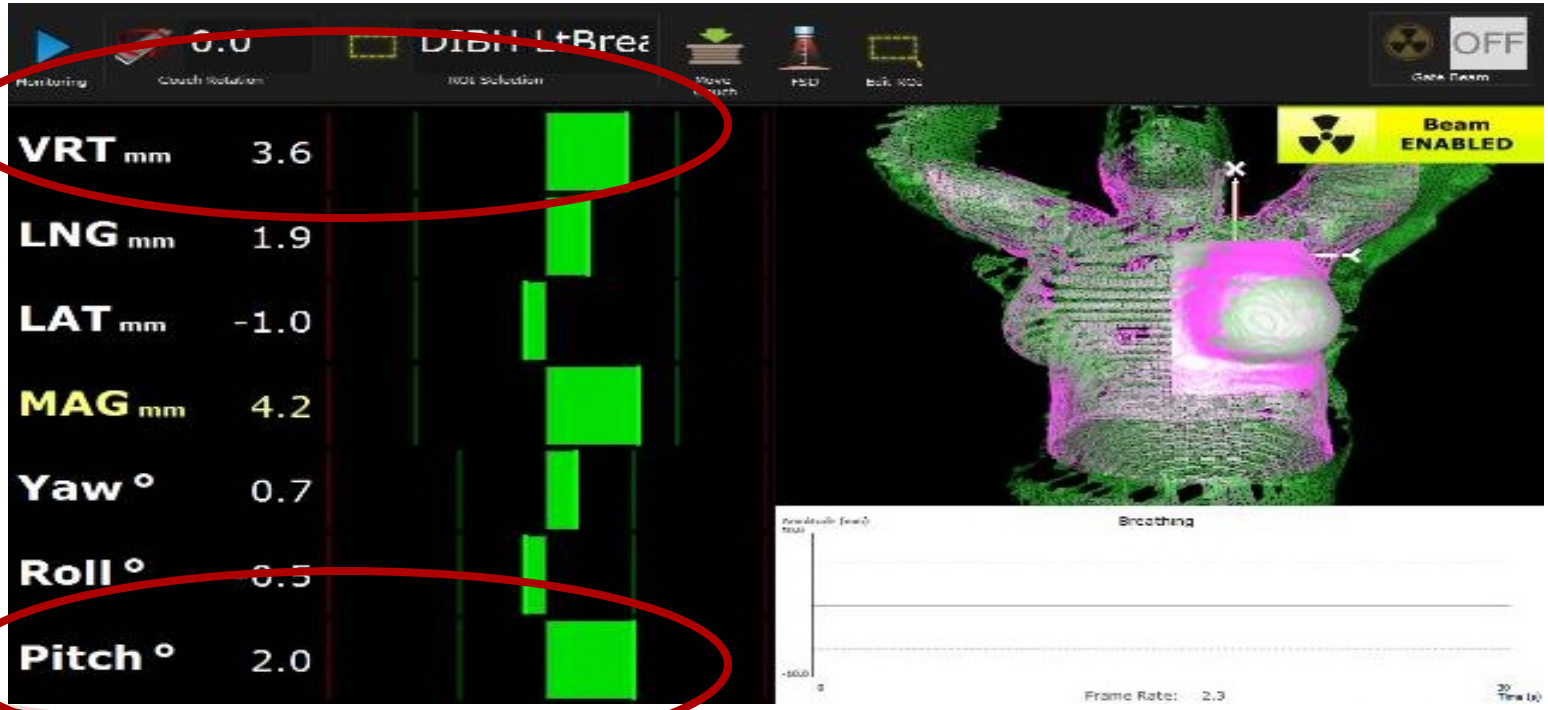
3. Common Pitfalls

- Learning Curve for SGRT

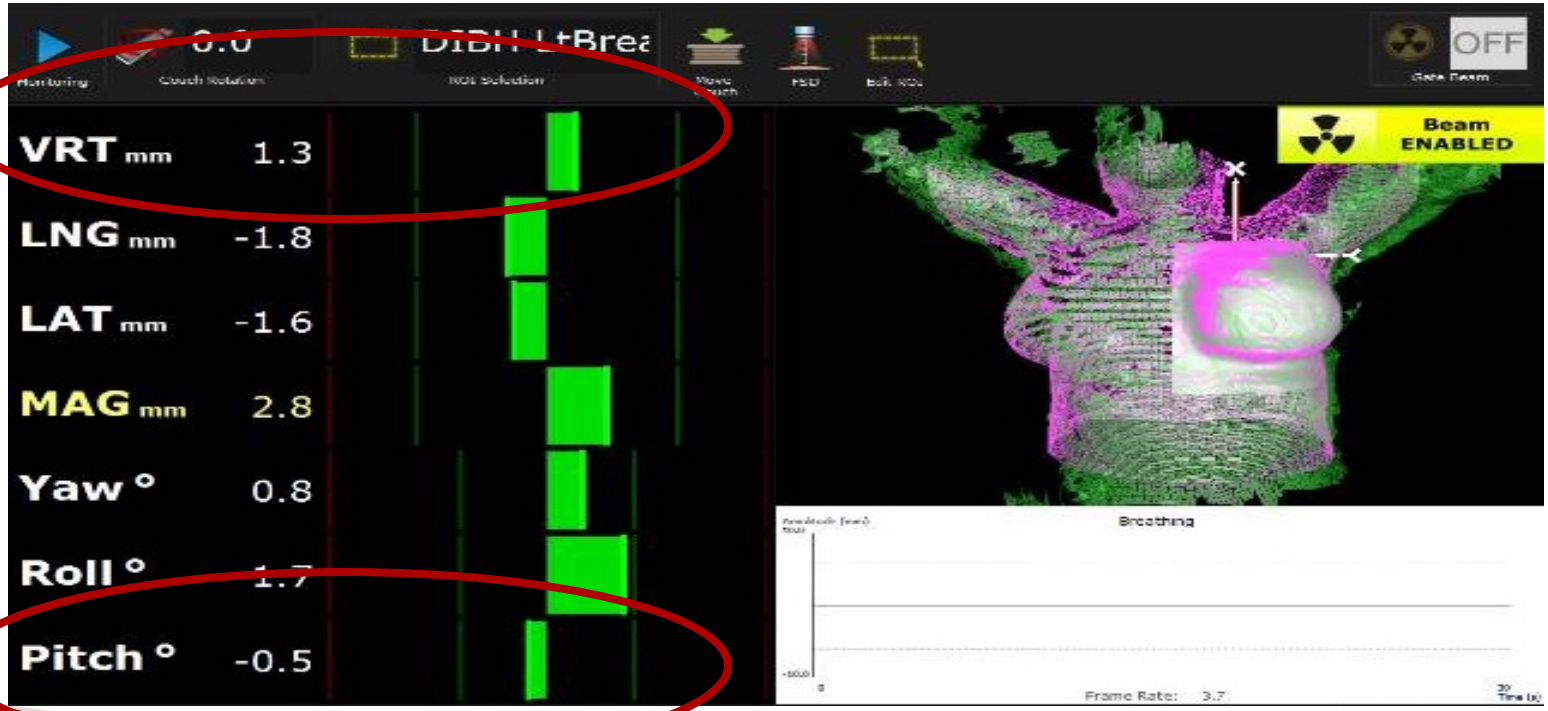
WBRT Example:
Setup Variability Day 7



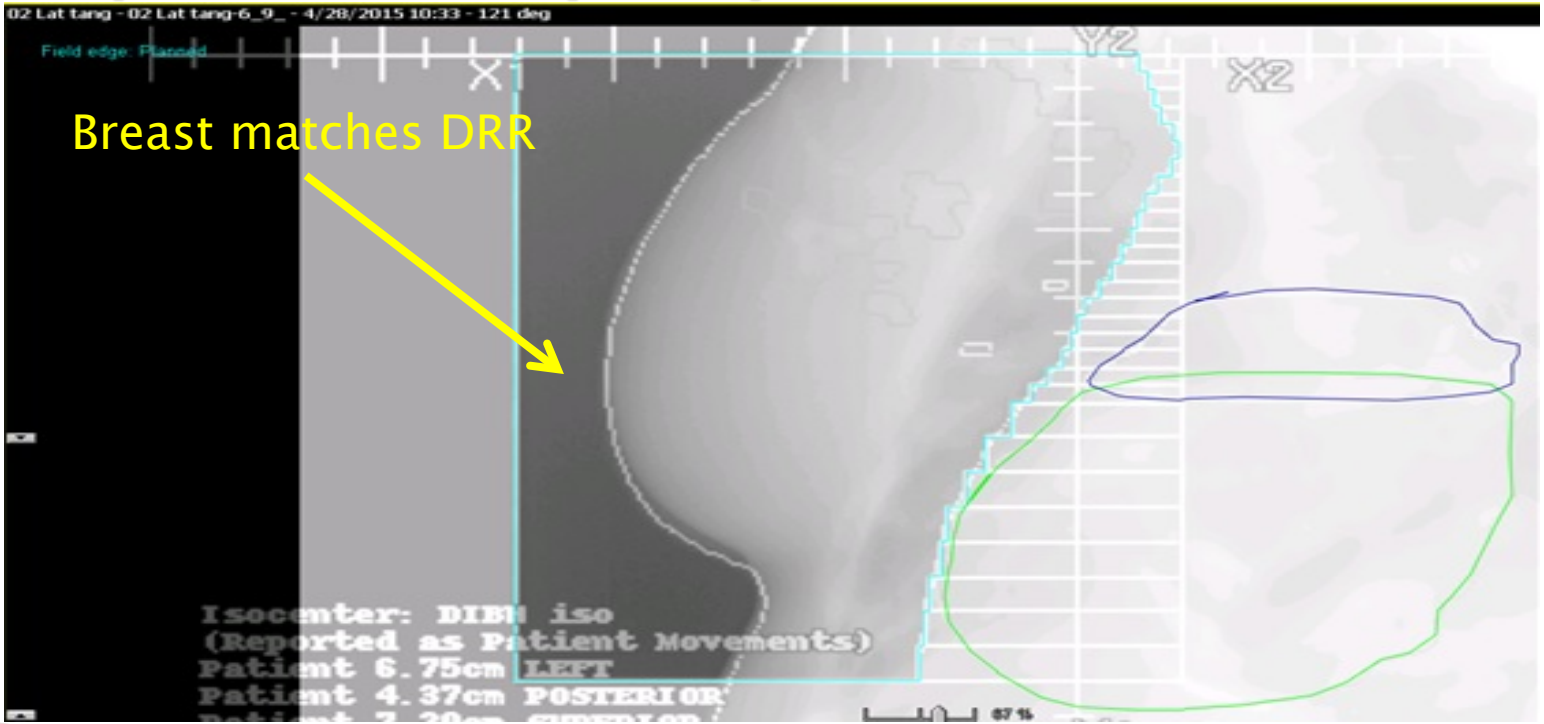
WBRT Example:
AlignRT Detects ↑ Pitch & VRT on Day 7



WBRT Example:
AlignRT No Pitch or VRT on Day 8



WBRT Example:
Setup Variability Day 8



Potential Solutions

- Train users to look at the surface images and not just the registration outputs
- Sufficient resources (QMP) must be devoted to implementation

Bastita et al, “Clinical paradigms and challenges in Surface Guided Radiation Therapy: Where do we go from here?” *Radiotherapy and Oncology*, 153: 34-42, 2020

Conclusions

- SGRT guidance of DIBH reduces OAR doses, improves efficiency & treatment quality
- TG-302 discusses workflow recommendations for DIBH
- Common pitfalls:
  - Patient changes: anatomic, breathhold, skin darkening
  - Learning curve
  - Lack of congruence with x-ray may be related to immobilization
- Potential solutions:
  - Good immobilization
  - Develop departmental workflows
  - Support therapists & communicate with MDs

Thank you for your attention!

Acknowledgements:
- TG-302 members
- Colleagues, therapists, & patients at University of Chicago Hospitals