Evaluation of a Surface Imaging System's Isocenter Calibration Methods

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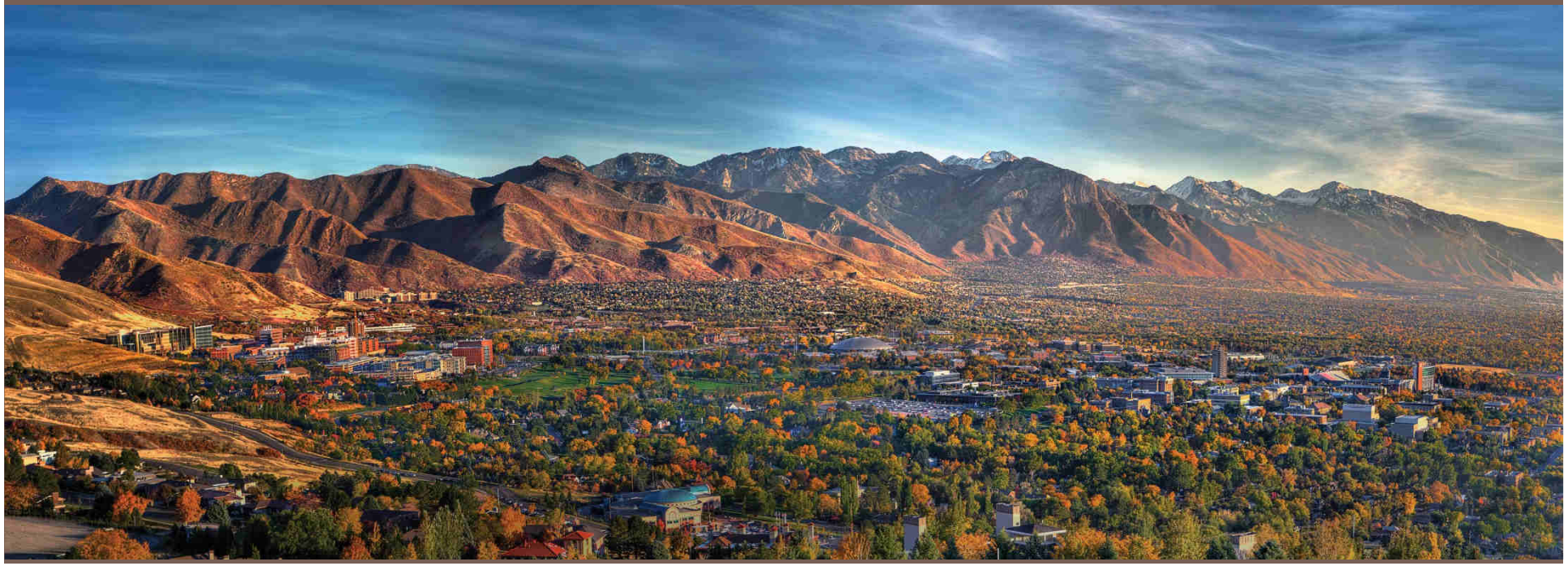
Rocky Mountain Chapter of AAPM Annual Meeting



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Conflicts of Interest

- None

Learning Objectives

To understand the:

- AlignRT surface imaging technology
- AlignRT clinical uses
  - With a focus on AlignRT for SRS
- Isocenter calibration methods used by AlignRT
  - “Monthly Calibration” and “Isocentre Calibration”
- Potential pitfalls of isocenter miscalibration

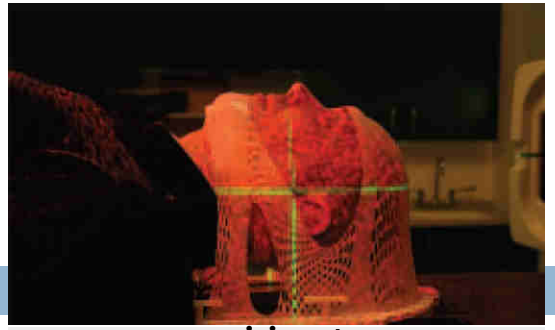
AlignRT

- Video-based 3D optical surface imaging system from VisionRT
- Utilizes 3 camera pods
  - 2 lateral, 1 front
- Random speckle pattern projected from each pod
- Visualized by each data camera

(Cervino et al., 2012)

www.visionrt.com

AlignRT



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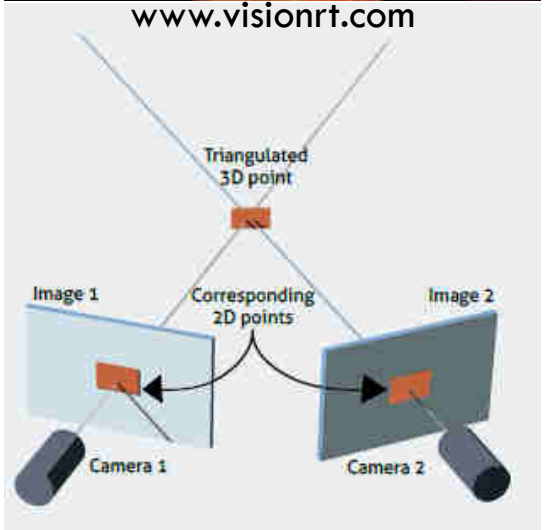
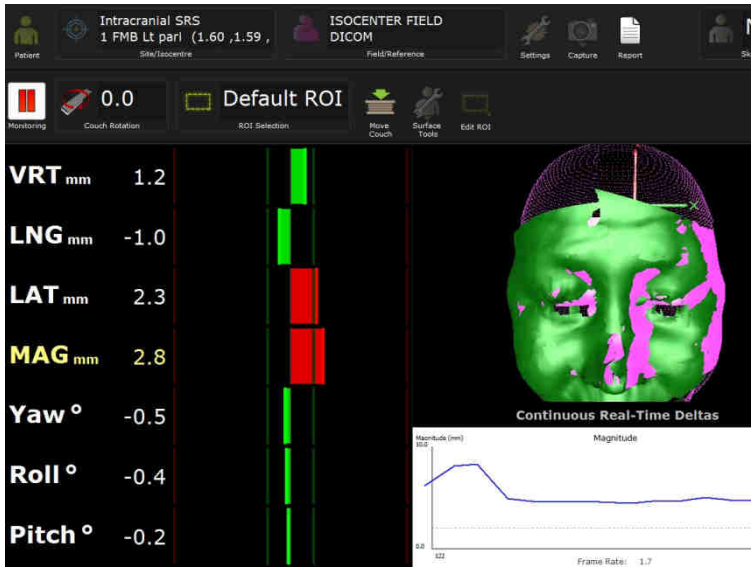
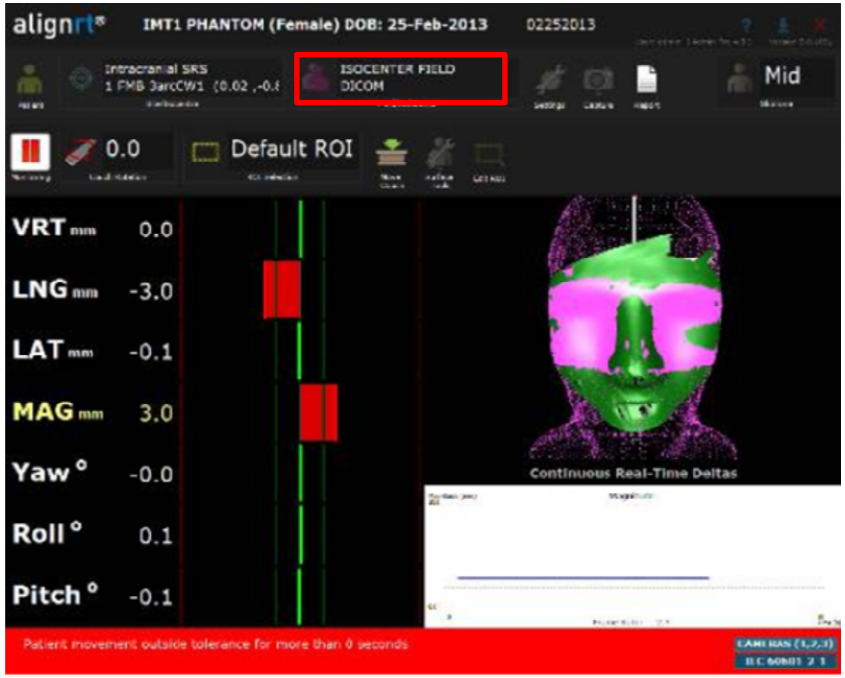


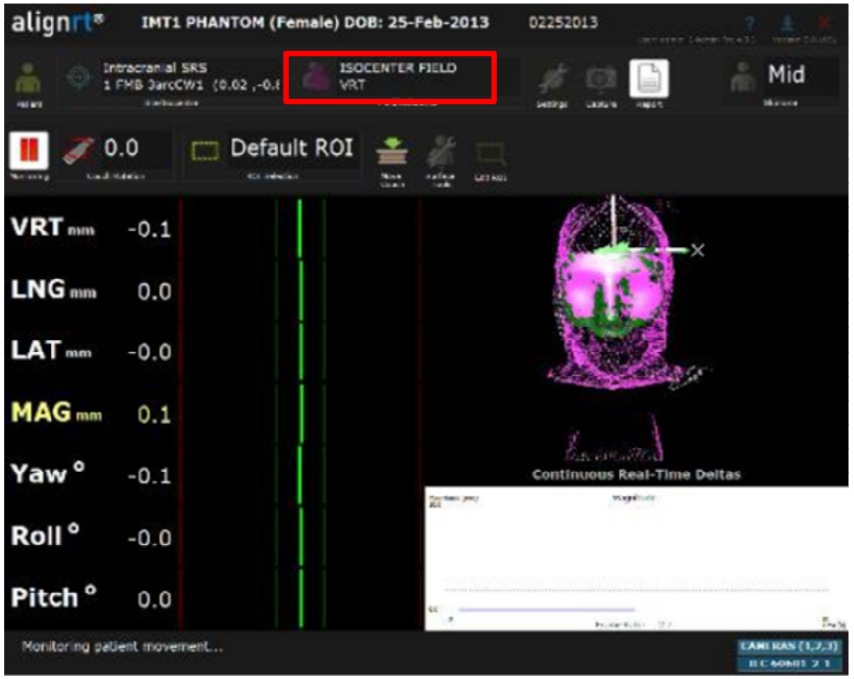
- Speckle pattern provides visual uniqueness to each point of the imaged surface
- 3D position of a set of points can be determined through triangulation
  - Camera calibration needed
- AlignRT calculates the displacement needed to align the imaged surface with the reference surface
  - Translations
  - Rotations



AlignRT

- Reference surfaces:
  - Imported body structure from TPS (“DICOM”)
  - Reference image captured with AlignRT (“VRT”)



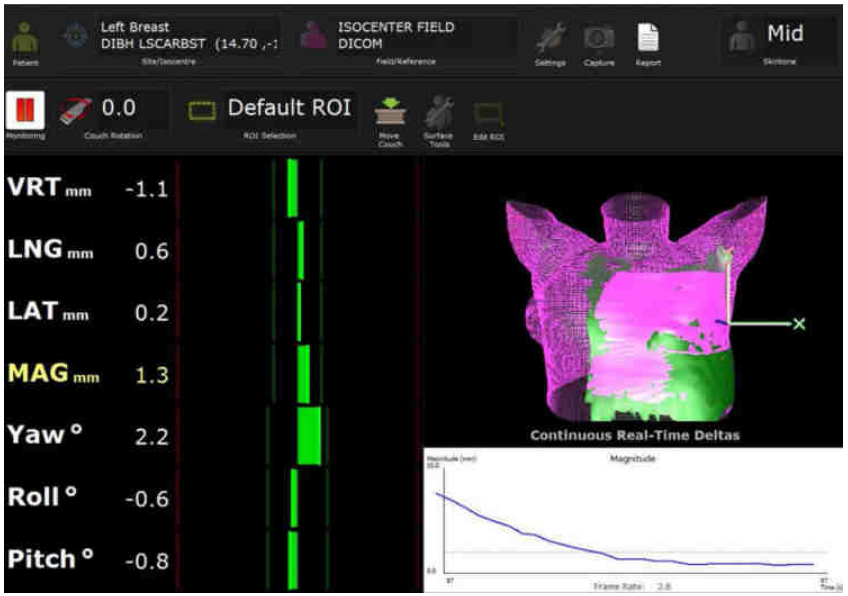


Clinical uses for AlignRT

- Breast
- Extremities
- Head and neck
- Frameless stereotactic radiosurgery (SRS)

Breast

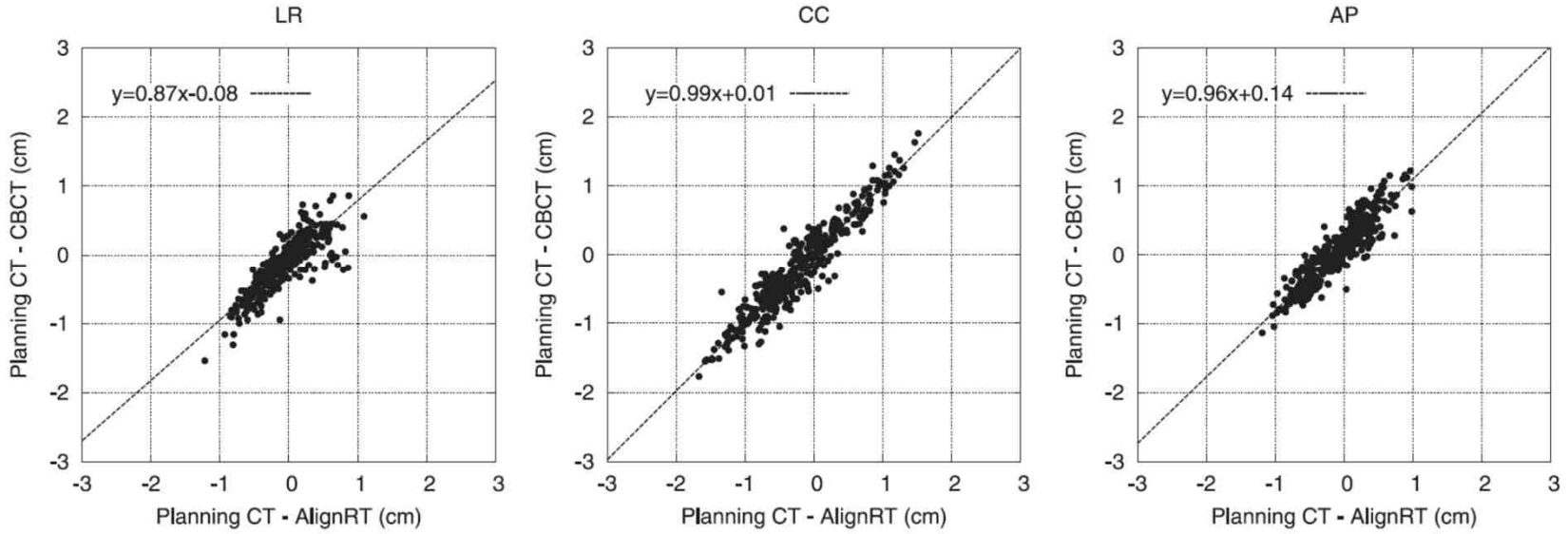
- Deep-inspiration breath-hold (DIBH)
  - To limit dose to the heart for left-sided treatments
- Patient breathes in to reach the same chest-rise as at the time of simulation
- AlignRT allow chest-rise to be evaluated and compared to simulation



(Walston et al., 2016)

Breast – accurate detection of position

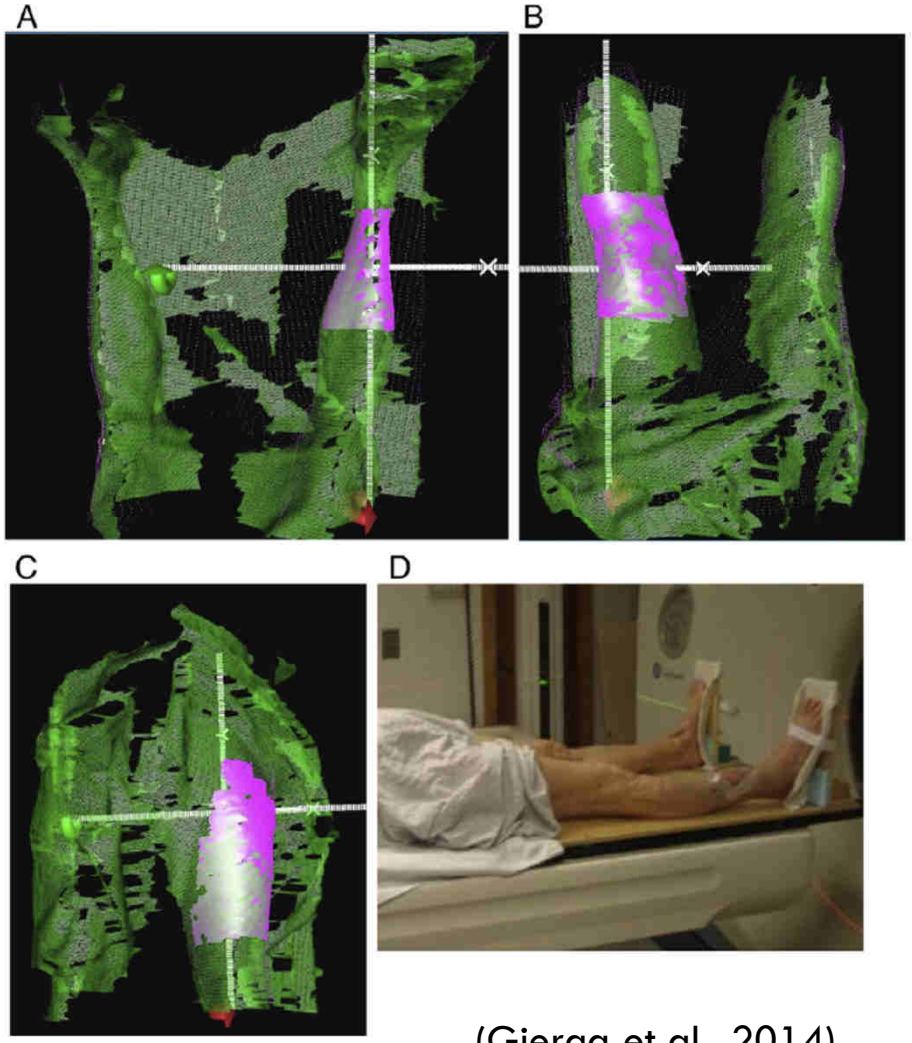
- AlignRT correlates well with CBCT for detecting setup errors during DIBH radiation therapy
- This accuracy supports the use of surface image guidance for this application



Alderliesten et al., 2013

Extremities

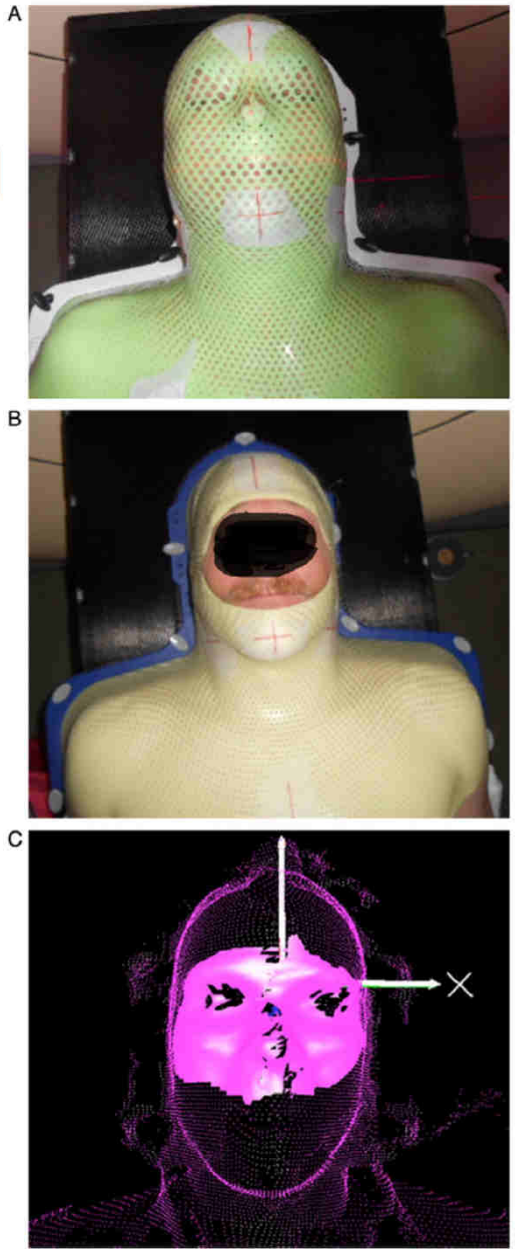
- Proper positioning of patient's with extremity sarcomas can be challenging
  - Frog leg
  - Long fields
- Surface imaging can aid in the initial positioning of the patient
  - Limb rotation prior to radiographic imaging
  - May prevent the need to repeat imaging



(Gierga et al., 2014)

Head and Neck

- Helpful for initial patient setup
  - (Gopan et al., 2012)
- Open face masks allows patient tracking and preserves patient immobilization
  - (Wiant et al., 2016)
  - Good for patients with anxiety
- Potential to evaluate neck flexion and shoulder position



(Wiant et al., 2016)

SRS

- System shown to accurately display displacements at the sub mm level
  - (Li et al., 2011)(Cervino et al., 2010)
- Open face mask to allow system to visualize facial surface for tracking position during treatment

SRS – Clinical outcomes

(2014)

Table 2 Comparison of local control and survival rates in retrospective studies of brain metastases treated with radiosurgery reporting kaplan-meier data[a]

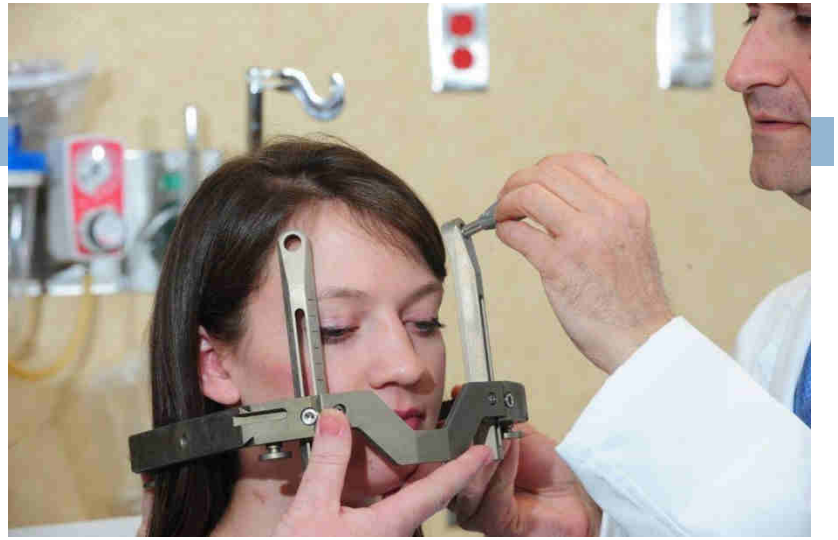
Study	Treatment system	Patients, n	Crude LC, %	Actuarial 1-yr LC, %	Actuarial 1-yr OS, %
Schomas *et al*. (19) [2005]	Frame-based LINAC	80	91	89	33
Bhatnagar *et al*. (18) [2006]	Frame-based Gamma Knife	205	***	71	37[b]
Brenenman *et al*. (6) [2009]	Frameless LINAC	53	***	80	44
Nath *et al*. (7) [2010]	Frameless LINAC	65	88	76	40
Pan *et al*. (17) [2012]	Frameless, surface-imaging guided LINAC	44	85	76	38
Present series	Frameless, surface-imaging guided LINAC	163	85	79	56

[a], LC indicates local control; LINAC, linear accelerator; ***, not reported; [b], estimated from Kaplan-Meier curve.

- Frameless, surface-imaging guided linac SRS can achieve outcomes comparable to other frame and frameless SRS techniques

AlignRT for SRS

- Advantages:
  - Real time tracking
  - Accurate – sub mm displacements
  - No biteblock
    - Able to treat patients without teeth
  - No ionizing radiation
  - Able to be used with couch rotations
  - No frame
    - Improved comfort
    - Hypo-fractionated treatments possible
      - No need for re-placement of frame
    - No scheduling needed for frame placement



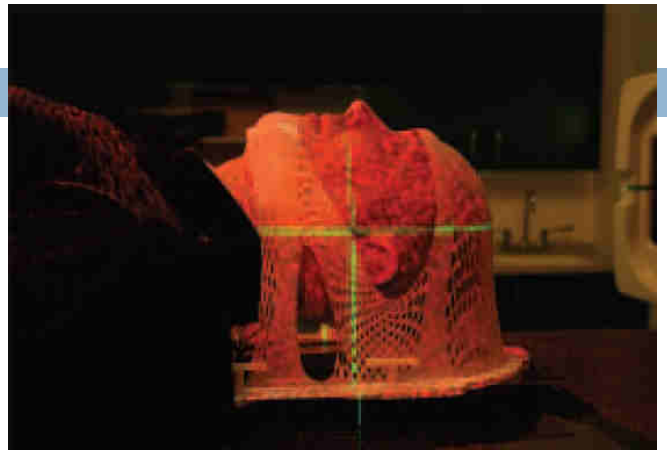
(Pan et al., 2012)

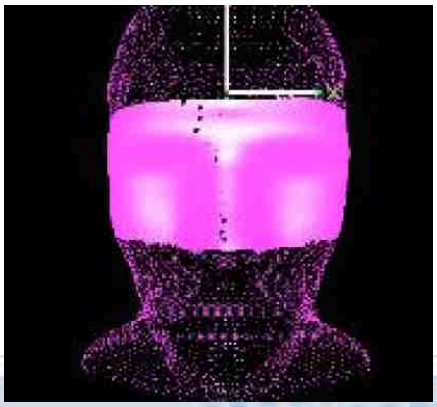
AlignRT for SRS

- Disadvantages
  - Using the face as a surrogate for targets within the brain
    - ROI selection important
  - Open face masks – not as immobilizing as a full mask or head frame
    - Tradeoff for real-time visualization of position
    - May not work with a non-compliant patient or someone not able to remain still

Typical workflow for SRS

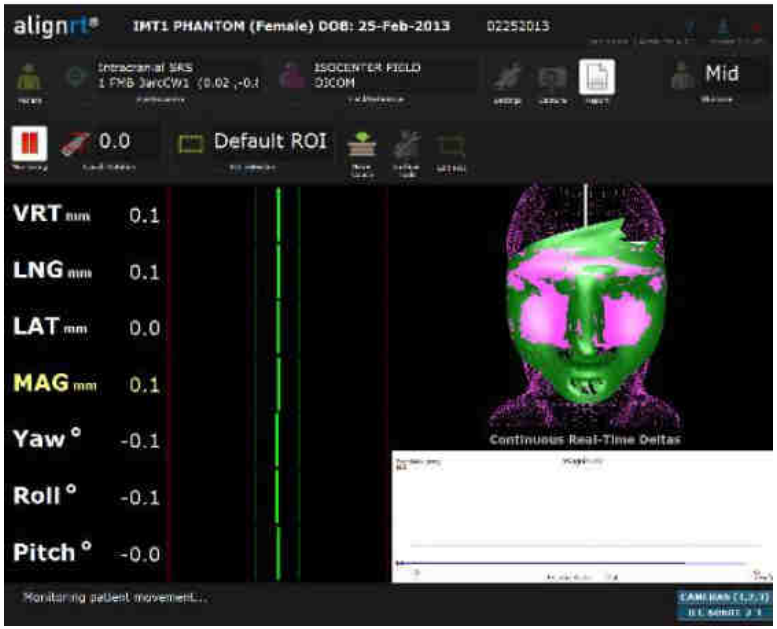
- CT sim with open face mask
- Define a ROI on CT-defined reference surface
- Setup head adjustment attachment on couch (if needed)
- Setup patient on the couch
- Apply shifts given to isocenter
  - Rough positioning
  - Adjust rotations (to limit additional adjustment)
- Place faceless mask and make shifts indicated by AlignRT until approximately zero
  - Fine positioning





Typical workflow for SRS

- kV/kV match to check for rotations (e.g., pitch)
- CBCT-indicated shifts are used to put patient in their final Tx position
- New reference image is captured with AlignRT (zero offsets)
- Monitor patient's position during treatment
- Discontinue treatment and reposition if offsets exceed a limit
  - 1mm
- Couch angle changed in AlignRT for beams utilizing couch rotations

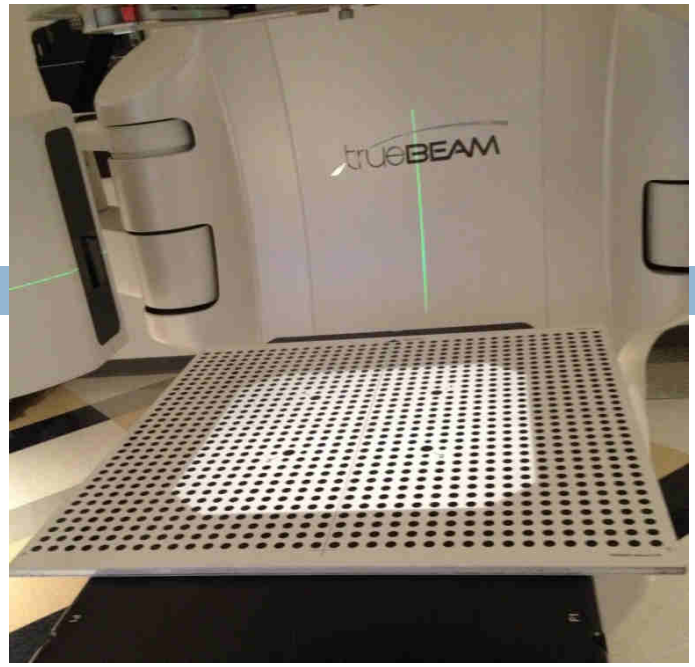


Evaluation of the two isocenter calibration methods

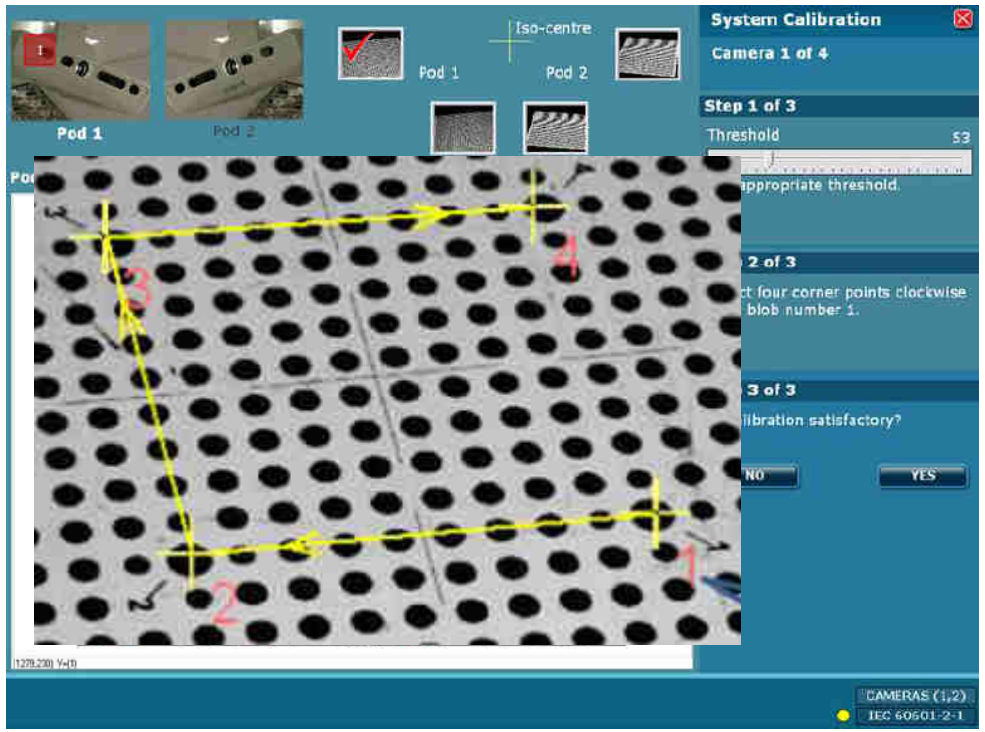
- AlignRT has two methods that can set the imaging system's isocenter
  - "Monthly Calibration"
  - "Isocentre Calibration"

- This work focused on the SRS workflow
  - Tighter tolerances typically required for SRS treatments
  - Couch rotations

Monthly calibration



- Calibration plate placed on couch and aligned with the room lasers or crosshair (100cm SSD)
- An image is captured with each of the cameras (6)
- The orientation of the board is determined with numbered blobs (1-4)
- The other blobs are detected
  - Known dimension and location
- Spatial correlation between the cameras is established



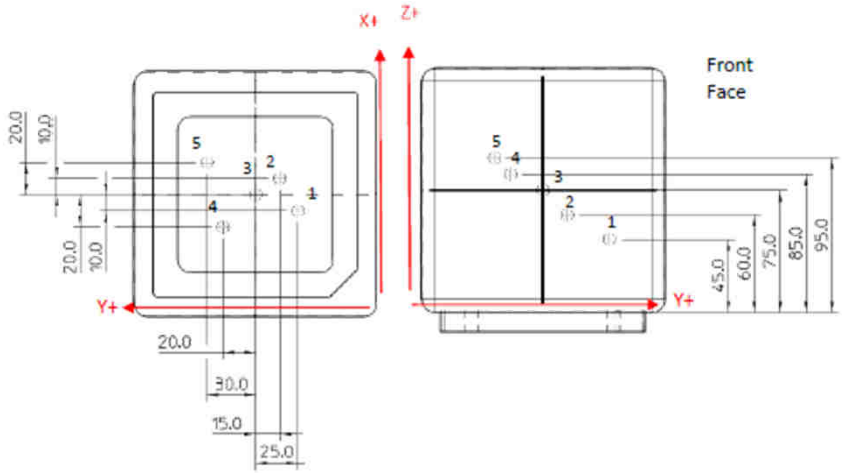
Monthly calibration

Potential problems:

- Aligned to isocenter using surrogates for actual isocenter
  - ODI, lasers, crosshair, etc.
- Couch may have inherent pitch or roll
- This work evaluates the effects of these potential miscalibrations

Isocentre calibration

- Completed in addition to the monthly calibration
- Utilizes a cube phantom that has five ceramic spheres
  - One is located in the center of the cube
  - The other four are arranged asymmetrically around the central sphere

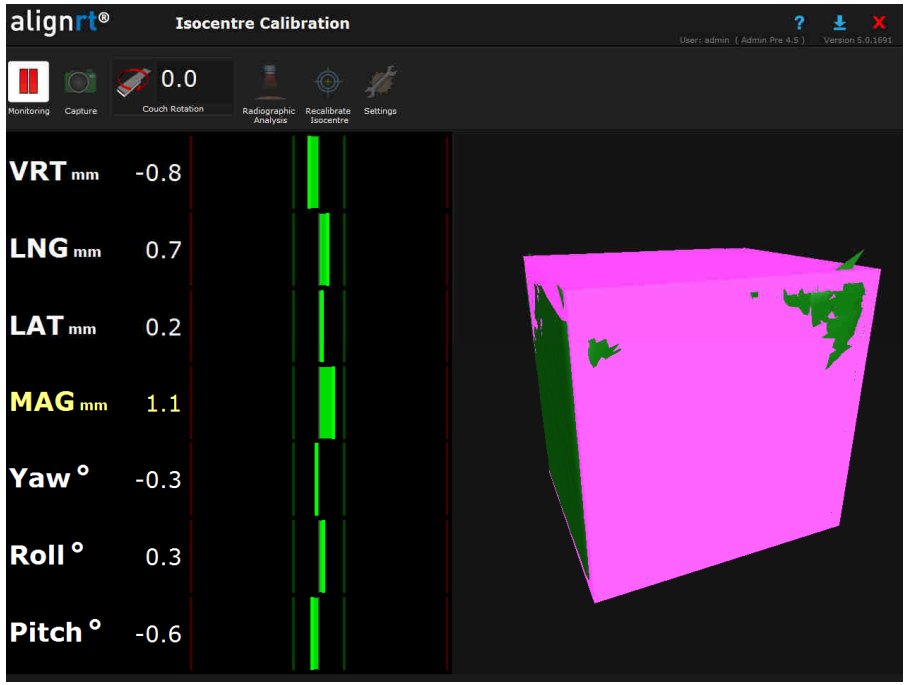


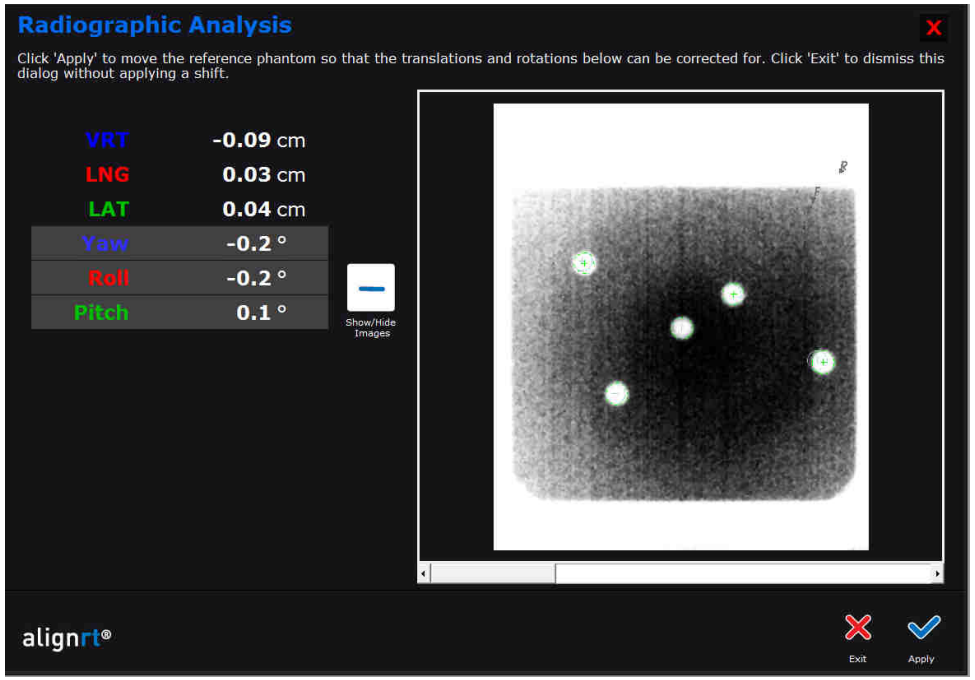
Isocentre calibration

- Position phantom using lasers and field light
- Take 4 MV port images of the cube phantom
  - AP, PA, L Lat, and R Lat
- Export dicom images to AlignRT
- Enter the isocenter calibration module in AlignRT
- Monitor with the cube phantom in place
  - Allows AlignRT to see the position of the cube relative to where it calculates it should be based on the board calibration
- Radiographic analysis of the MV images
  - Determines offsets/rotations of the cube from MV isocenter
- Apply the isocenter calibration
  - Creates a 4x4 matrix of rotations/shifts of the board calibration to the MV isocenter

Isocentre calibration

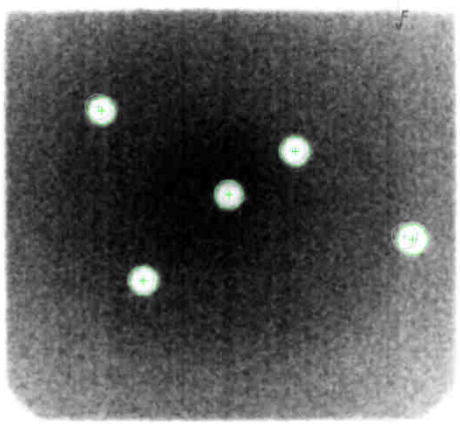
- Isocenter calibration module screens:



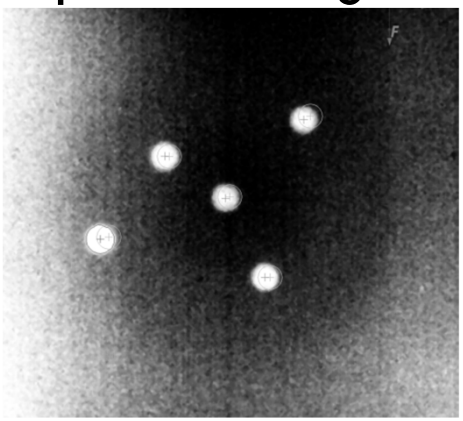


Isocentre calibration

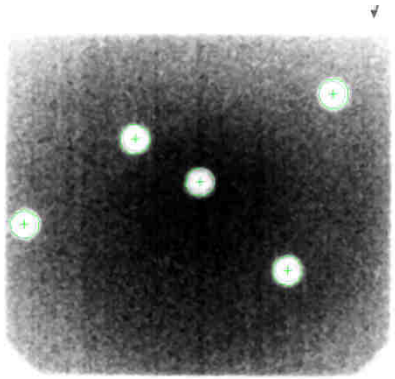
- Radiographic analysis of the portal images
- 4x4 matrix to reposition AlignRT isocenter



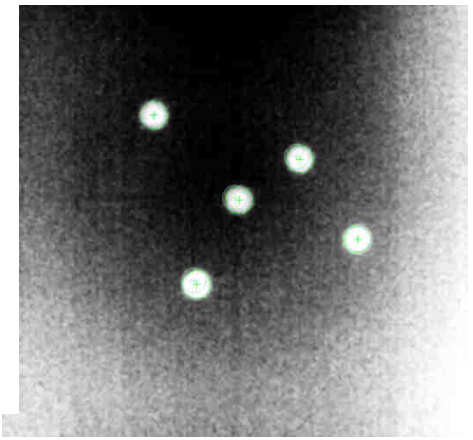
PA



R Lat



AP

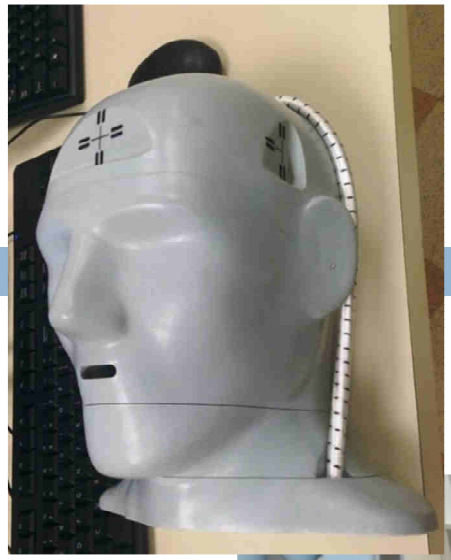


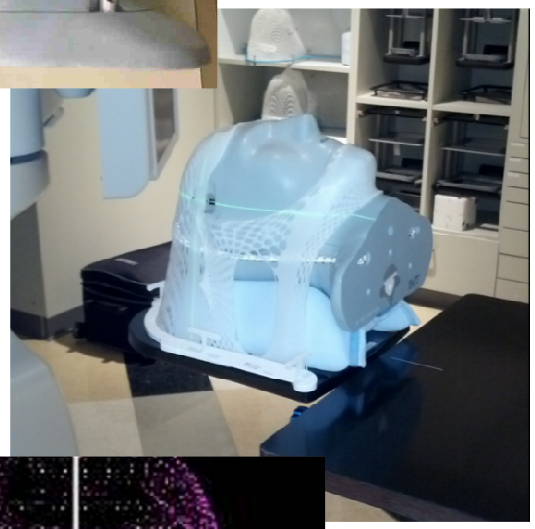
L Lat

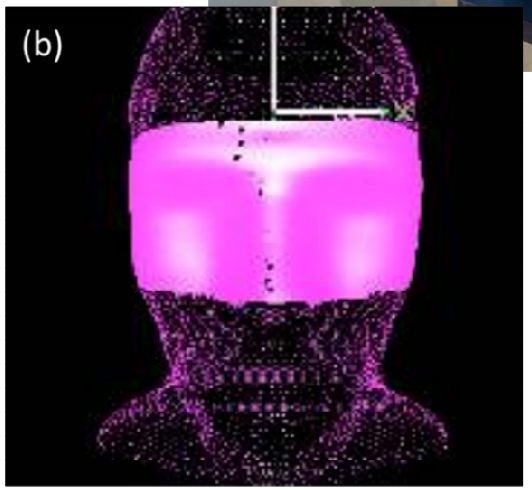
0.999997	-0.00175	0.001581	0.226326	Lng
0.001763	0.999987	-0.00486	0.127327	Lat
-0.00157	0.004864	0.999987	-0.11187	Vrt
0	0	0	1	

Head phantom

- MAX-HD anthropormorphic head phantom
- SRS treatment setup was replicated
  - Open-face mask
- Treatment plan was created with iso roughly centered in the brain
  - Included fields with couch rotations of 0, 45, 90, 315, and 270°
- Plan and body structure exported to AlignRT
- ROI was defined as open areas of face
- Initially positioned with kV CBCT







Displacements with intentional miscalibrations

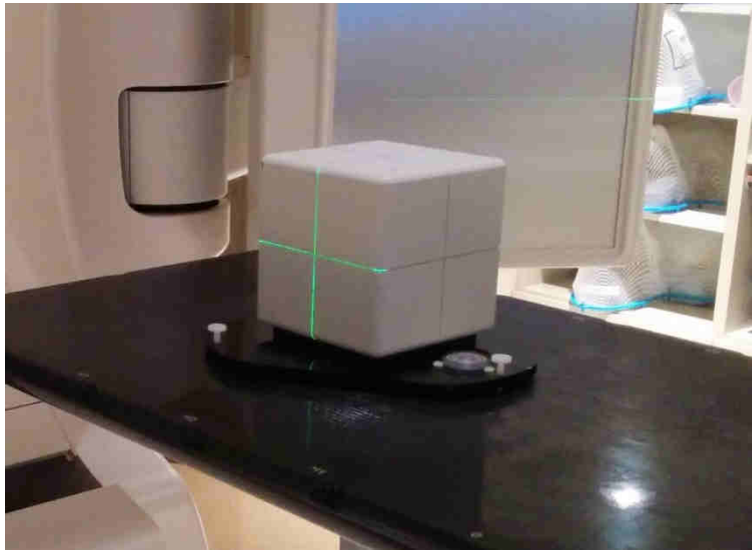
- Calibration plate was intentionally shifted away from the linac isocenter in one direction before monthly calibration
  - ± 3mm in the lng and lat directions
  - ± 1mm in the lng, lat, and vrt directions
- Head phantom returned to position indicated using CBCT
- Tracking started with CT-defined reference surface
- AlignRT-indicated offsets were recorded at 270 , 315, 0, 45, and 90° couch angles for each intentional calibration misalignment.

Displacements with intentional miscalibrations

- Repeated for each miscalibration, but with an AlignRT-captured reference surface:
- Head phantom returned to position indicated using CBCT
- A new AlignRT reference surface was captured with the couch at 0°
- AlignRT-indicated offsets were recorded at 270 , 315, 0, 45, and 90° couch angles for each intentional calibration misalignment

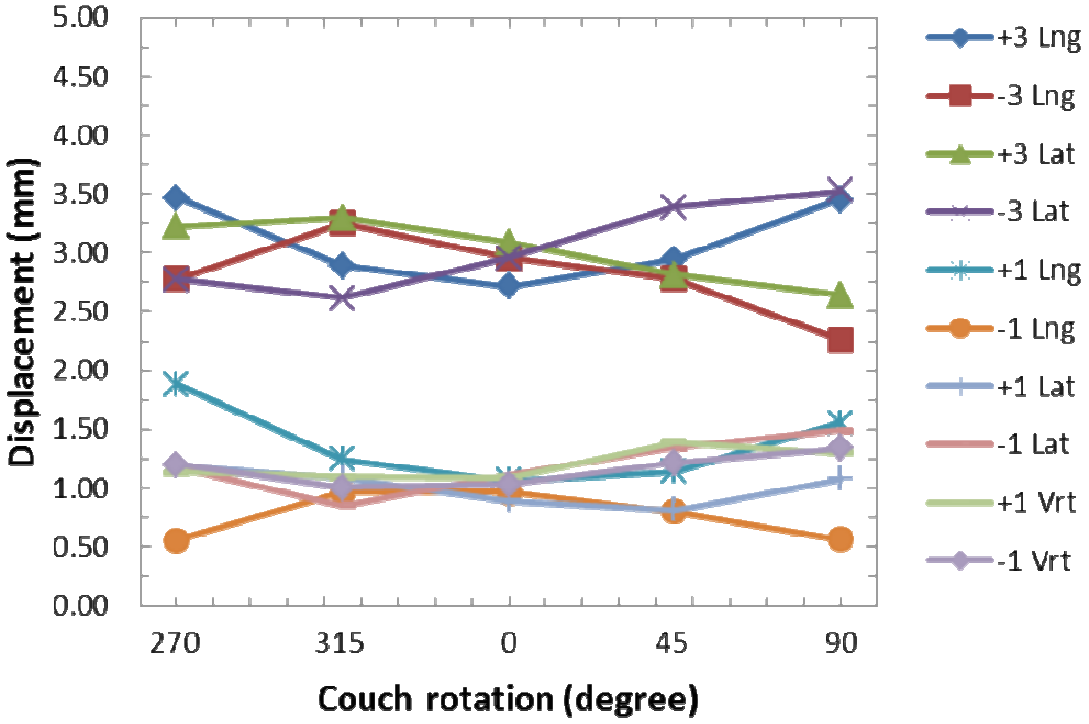
Displacements after isocentre calibration

- Following each miscalibration of the monthly calibration, an isocentre calibration was completed
- An AlignRT-captured reference surface was used (from couch at 0°)
- AlignRT-indicated offsets were recorded at 270 , 315, 0, 45, and 90° couch angles for each intentional calibration misalignment

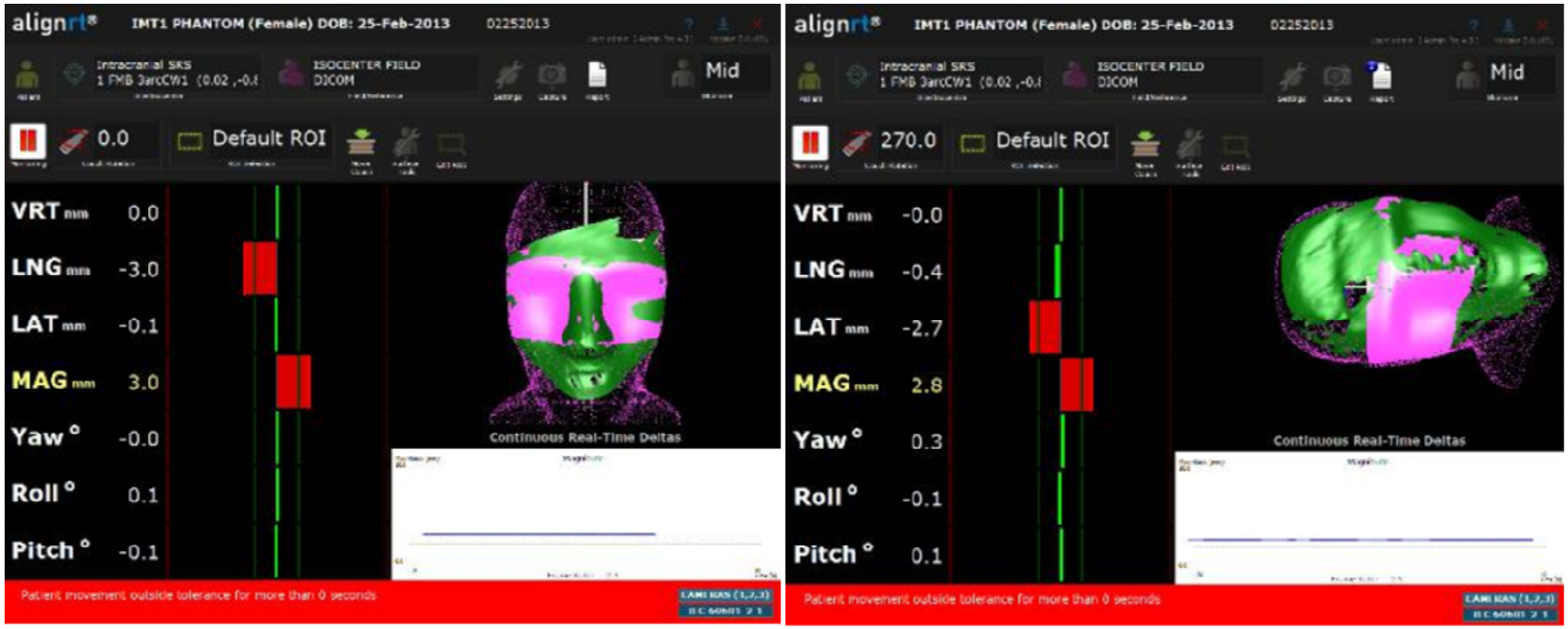


Results: CT-defined ref surface

- Displacement magnitude approximately constant with couch rotation
  - Plots flat in shape
- Average displacements for 3.0 and 1.0 mm miscalibrations were 3.0 and 1.2 mm, respectively
  - Approximately equal to the miscalibration magnitude



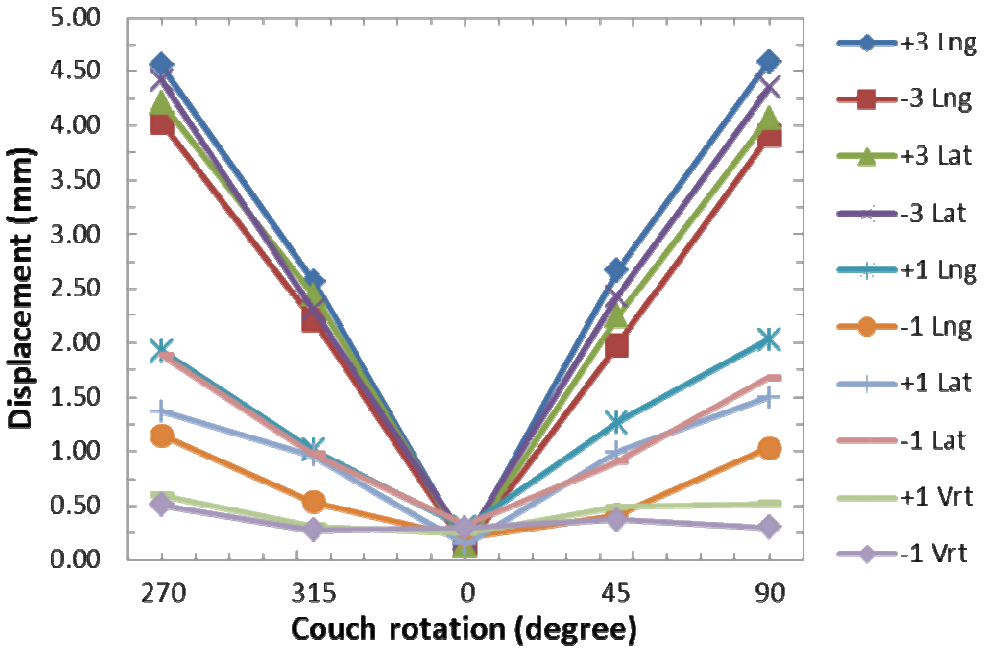
Example: -3mm lng miscalibration



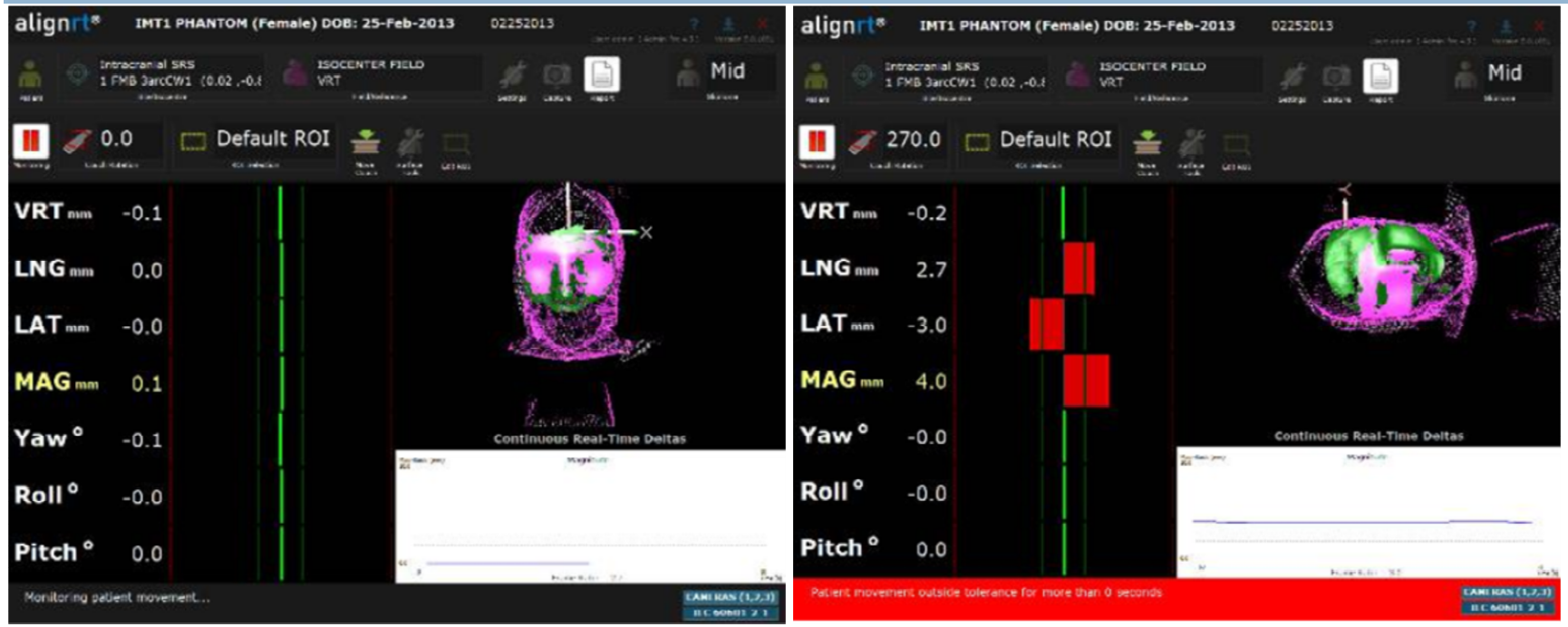
- Rotating from 0 to 270°, the total displacement remains constant
- The direction of the displacement changes from lng to lat – staying the same relative to the room

Results: AlignRT-captured ref surface

- Displacement magnitude increases with couch rotations for lng and lat miscalibrations
  - Faster increase for larger miscalibrations
- Average displacement at 0° was 0.2mm
- Average displacement at ±90° was 4.3 and 1.6mm for 3.0mm and 1.0mm miscalibrations
- For vrt miscalibrations, the largest indicated displacement was 0.6 mm



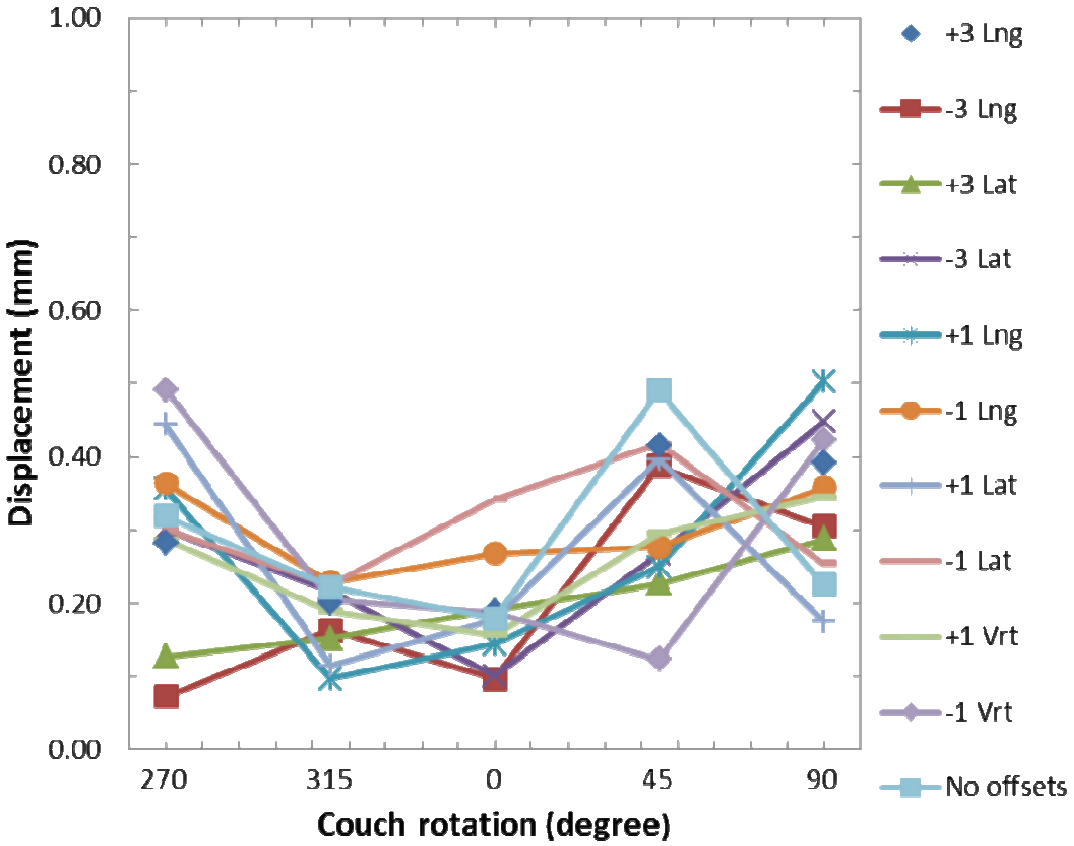
Example: -3mm lng miscalibration



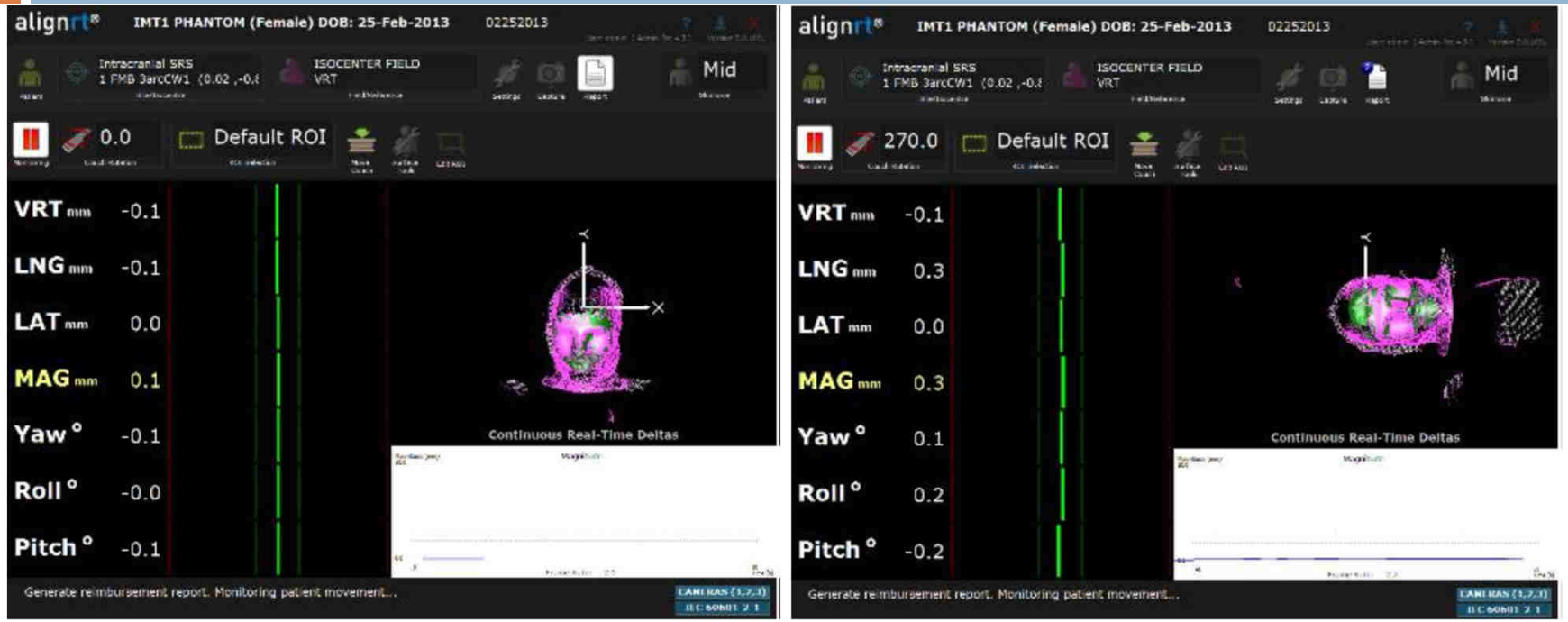
- Rotating from 0 to 270°, the total displacement increased from 0.1mm to 4.0mm
- Offsets in both the lng and lat directions

Results: after isocentre calibration

- With an AlignRT-captured ref surface
- Displacements ranged from 0.1 to 0.5mm for all couch rotations
- These values are within the expected range of walkout observed for this couch from ongoing QA tests



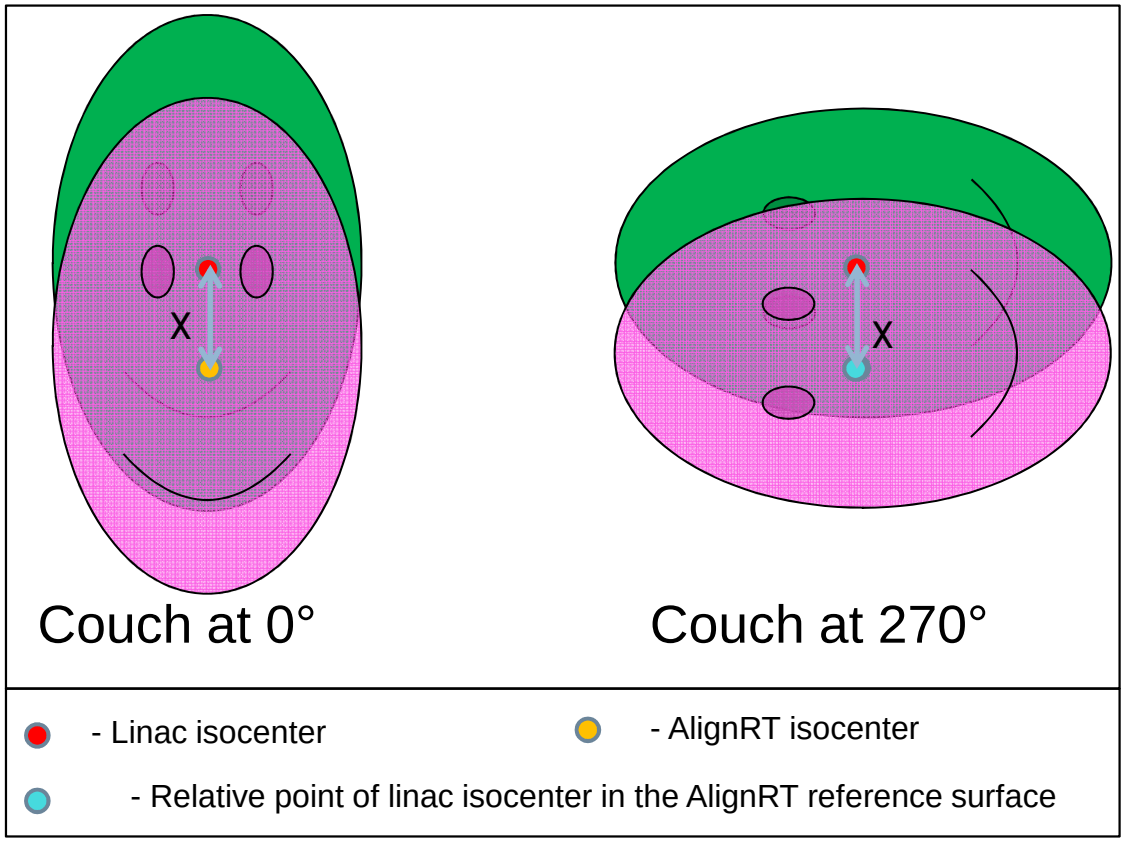
Example: after isocentre calibration



- Rotating from 0 to 270°, the total displacement increased from 0.1mm to 0.3mm

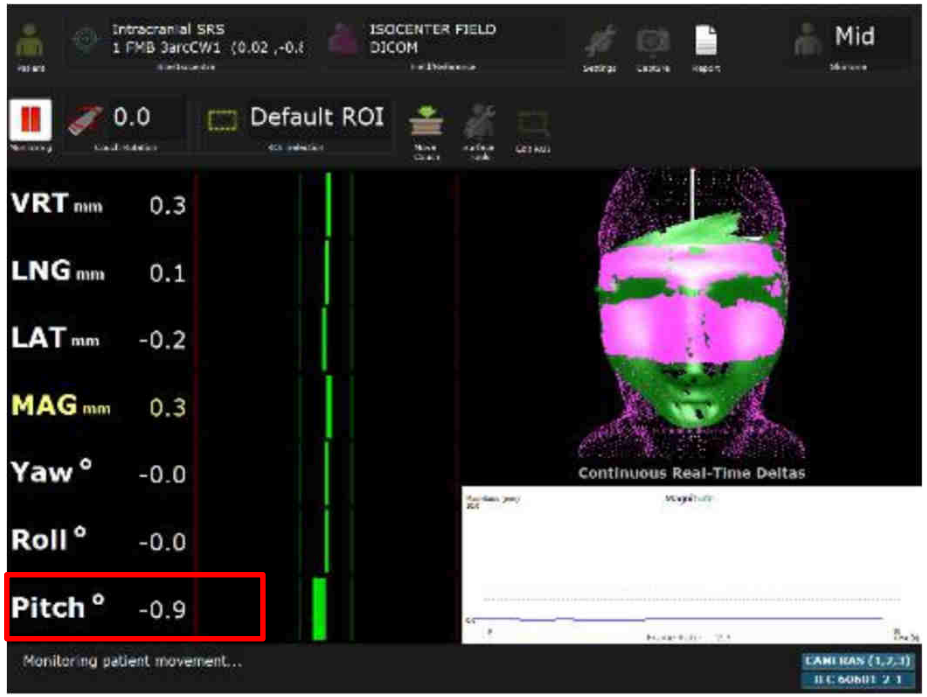
Discussion: CT-defined ref surface

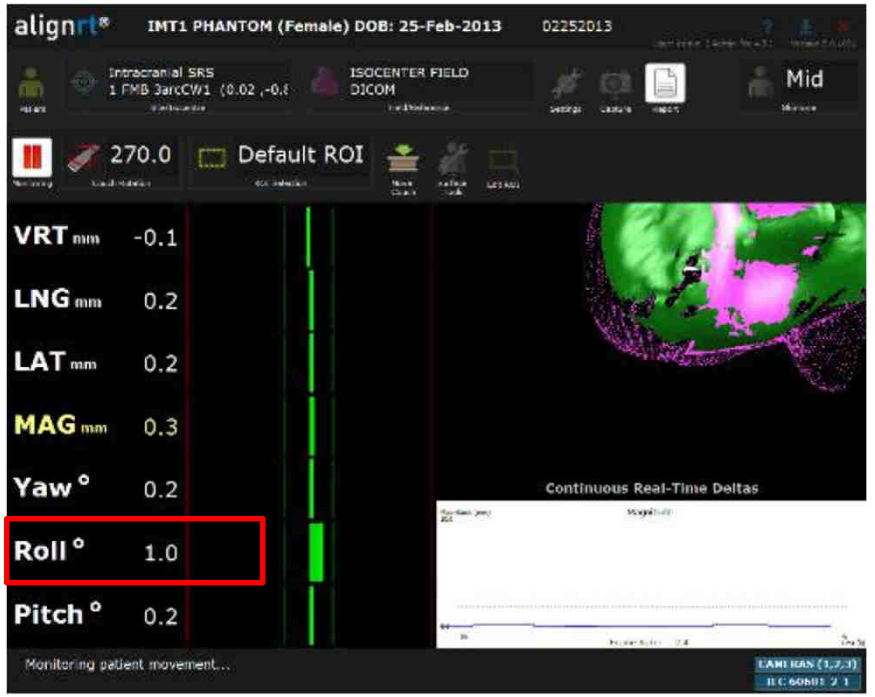
- Miscalibrations result in systematic offsets in the reference surface
- Relevant for when AlignRT is used for initial patient setup or DIBH
  - DIBH
  - Extremities
  - H&N
- Careful placement of the calibration plate is needed to limit these effects



Discussion: CT-defined ref surface

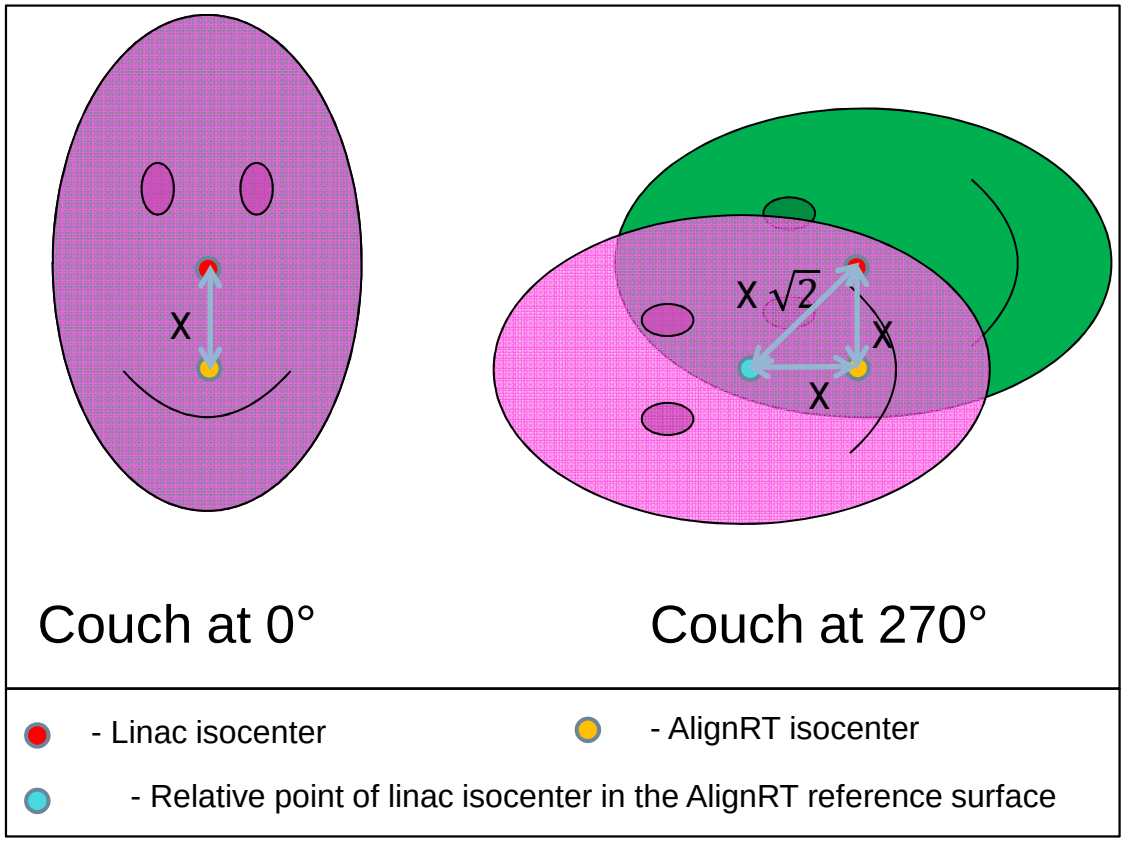
- Intentially miscalibrated with the calibration board pitched 1°
- Rotational miscalibrations also propagate





Discussion: AlignRT-captured ref surface

- Based on geometry alone, the displacements should be equal to X $\sqrt{2}$ for lng and lat miscalibrations
- This would be 4.2 and 1.4mm for 3.0 and 1.0mm miscalibrations, respectively
- The average were 4.3 and 1.6mm
  - Include some couch walkout



Discussion: AlignRT-captured ref surface

- For Vrt shifts:
  - Calibration offsets were along axis of rotation
  - Offsets are independent of couch rotation
  - All displacements within 0.6mm for all couch angles
- Isocentre calibration resolves the miscalibration artifacts observed with couch rotations

Isocentre calibration

- Based on geometry, a $\sqrt{2}/2$ (0.7mm) miscalibration would result in a 1.0mm displacement at 90° couch rotations
- 4x4 matrix to reposition AlignRT isocenter… from before

~ 0.3 mm displacement

0.999997	-0.00175	0.001581	0.226326	Lng
0.001763	0.999987	-0.00486	0.127327	Lat
-0.00157	0.004864	0.999987	-0.11187	Vrt
0	0	0	1	

0mm offsets

0.999996	-0.0029	3.73E-05	0.346394	Lng
0.002902	0.999986	-0.00448	2.95379	Lat
-2.43E-05	0.00448	0.99999	-0.11833	Vrt
0	0	0	1	

+3mm Lat offset

- Positioning the calibration board within 0.7 mm of isocenter could be challenging

Conclusions

- The potential pitfalls of the monthly calibration method have been demonstrated
- The advantages of the isocentre calibration method have been established.
  - Effectively removes the potential miscalibration artifacts of the monthly calibration
  - Especially critical for methods that require tight tolerances and utilize couch rotations
  - Less critical for treatments that do not have these requirements – provided the monthly calibration was performed carefully

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- Thank you for your attention

Questions?

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