SURFACE GUIDED RADIATION THERAPY(SGRT)

"Enhancing Accuracy, Safety,and patient Comfort in Daily practice"

Naveen Kumar, DMRT, B.Sc(RT)

Ida B Scudder Cancer Centre
Christian Medical College Hospital, Vellore

Our Vision

The Christian Medical College Vellore seeks to be a witness to the healing ministry of Christ, through excellence in education, service and research.

"Not to be ministered unto but to minister" Mark 10:45

Radiotherapy Technology and Services at CMC

- Linear Accelerator (Varian Clinac 2100C/D, TrueBeam STx (2)
  - One Truebeam with Brainlab EXACTRAC and SGRT)
- Tomotherapy
- Telecobalt (Equinox 80)
- HDR brachytherapy (Elekta Flexitron)
- CT Simulator (Siemens Somatom, GE Discovery)

 RADIATION THERAPY	224 BRACHYTHERAPY	806 CHEMOTHERAPY	2977 RADIATION THERAPY TREATMENT	127 SRS & SRT

Why this talk?

Quality assurance for nonradiographic radiotherapy localization and positioning systems: Report of Task Group 147

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AAPM TG147

- *Steep dose gradients* achieved by IMRT techniques (e.g. SBRT)
- Increasing *CTV to PTV margins* to account for internal motion increases undesirable irradiation of normal tissue.
- *Inter-fraction variations* including weight loss, organ-filling etc. requires verification. (SGRT is a non-radiographic alternative)
- *Intra-fraction variations* and movements must be followed real time.

Non-Radiographic Localisation Techniques

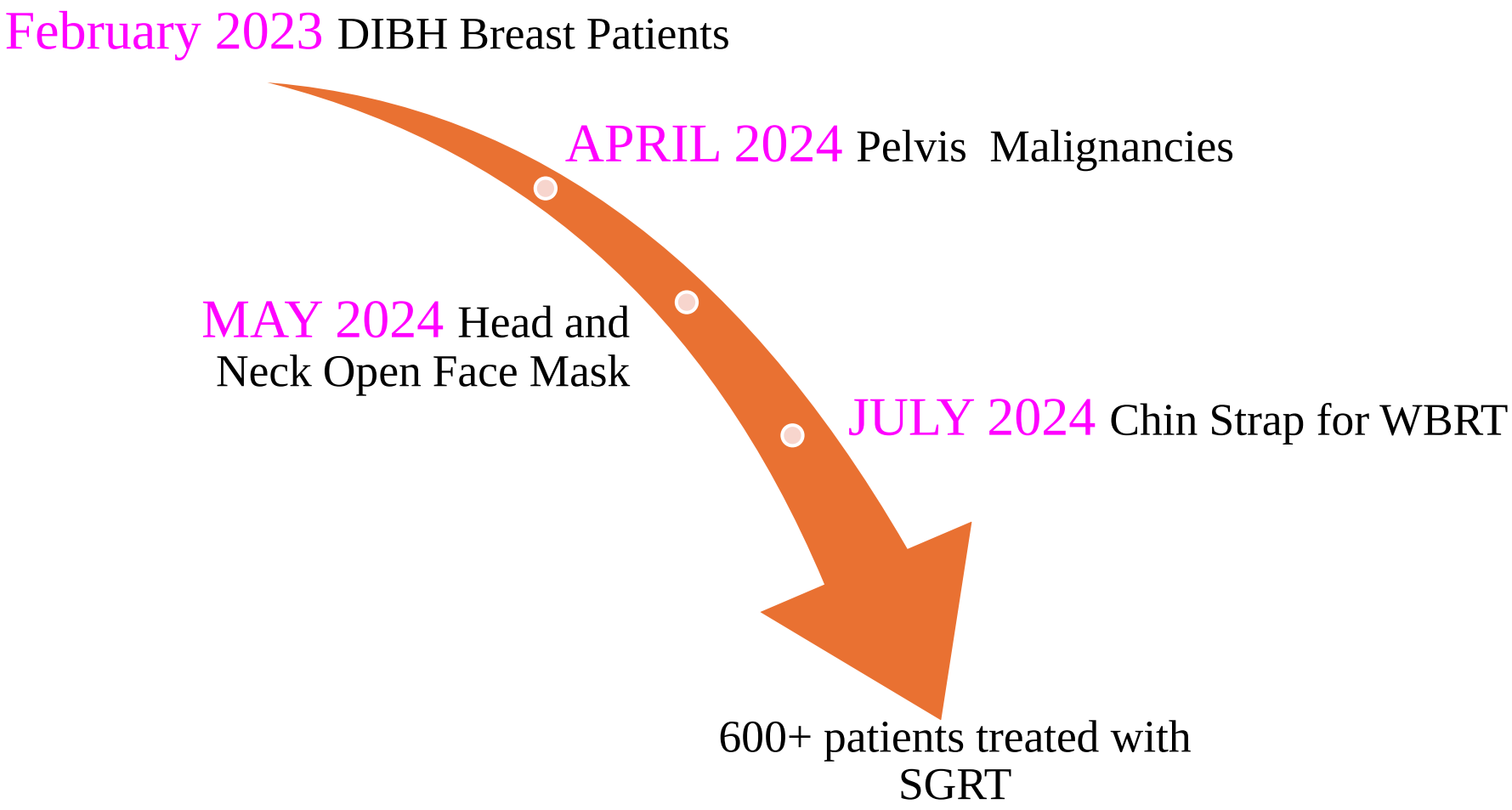
➢ **Marker – based**

- Passively track a reflective marker with an imaging system operating in the infrared spectrum
- Actively track a radiofrequency(RF) beacon using a set of RF receivers

➢ **Surface – based**

- Mapping of many arbitrary points on the patient while simultaneously tracking their position over time
- These points comprise a 3D surface and can be considered an extension of a marker –based approach

SGRT IN CMC


February 2023 DIBH Breast Patients
APRIL 2024 Pelvis Malignancies
MAY 2024 Head and Neck Open Face Mask
JULY 2024 Chin Strap for WBRT
600+ patients treated with SGRT

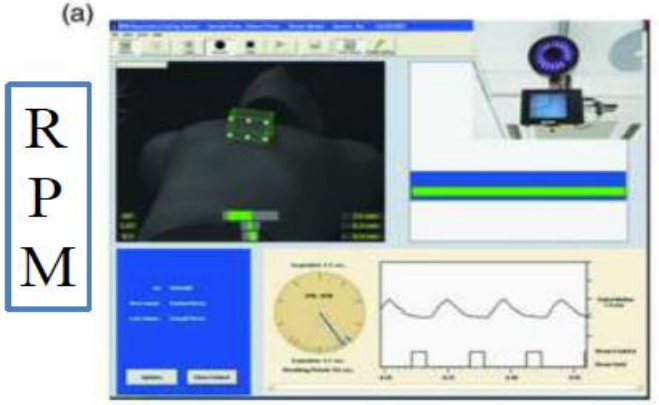
Motion Management before VisionRT

Respiratory Gating technology was implemented in both the Campuses with help of Varian RPM and RGSC systems

- IR tracking camera and reflective marker environment
- DIBH (Carcinoma Breast, HCC Liver)
- 4DCT-based MIP with backup gating (Carcinoma Lung, Mediastinal lymphoma, Thymoma)

  3 days of breathing training

  Visual Coaching



VisionRT (Since Feb 2023)

SimRT (planning and Simulation for DIBH)

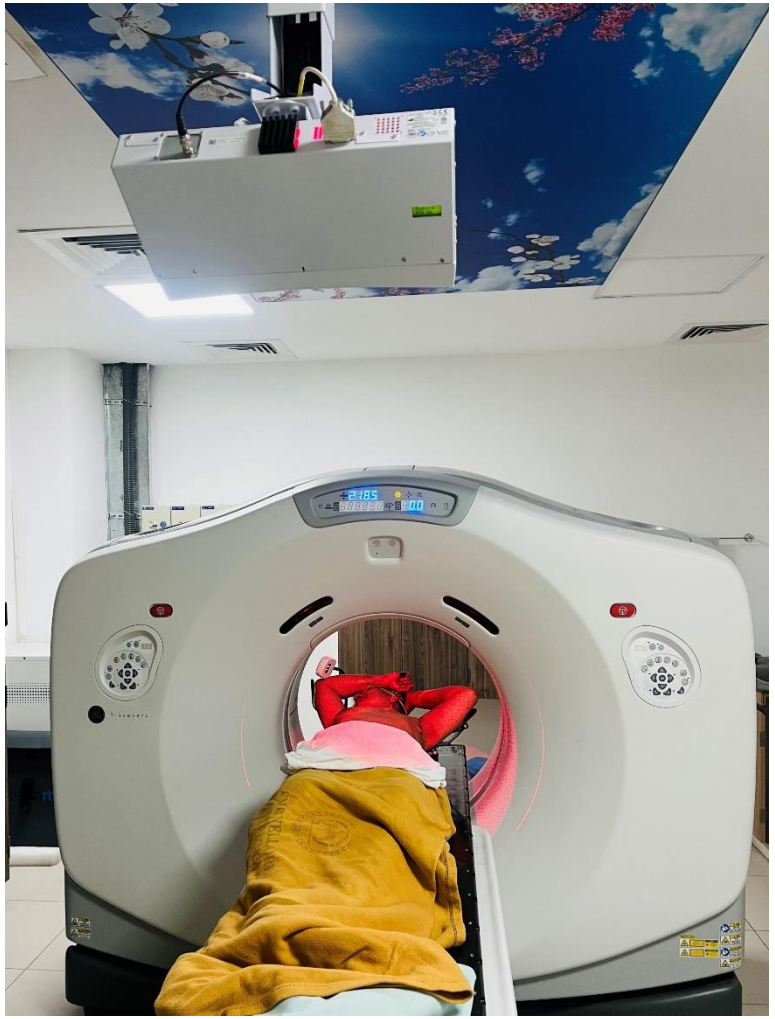
Selection Criteria for **DIBH**

- Co-morbidities
- General fitness of the patient
  - ➢Must be able to hold the breath for at least 15 -20 seconds)
  - ➢Reproducibility of the breathing pattern

Vision RT

Sim RT (planning and Simulation for DIBH)

- Patient education and positioning
  Breast Board
- CT Acquisition
  - Free breath (FB)
  - DIBH
- CT Analysis
  - Position of the heart will be compared



Align RT

Patient Setup and Treatment

- **Import DICOM**
  - Approved plan, 2 CTs and Structure sets
  - FB CT Reference (For positioning)
  - DIBH CT Reference (For treatment)

- Fine-tune the patient setup with **Postural Video**

Align RT….

- Orthogonal kV imaging to be performed and shift applied
- Recapture reference surface within same DIBH
- Threshold for Acceptability

✓ 3mm is our tolerance

- Deliver treatment with DIBH

✓ Real-time surface monitoring by AlignRT

Postural Video

- Helps to setup the patient with a Multi-angle real-time view
- Helps overcome the limitation of FOV of OBI for large targets
- Patient setup error is observed to have reduced
- Overall setup time is also reduced

SGRT in Pelvic Targets

The pelvis is a complex region containing several important organs such as the bladder, rectum, and reproductive organs.

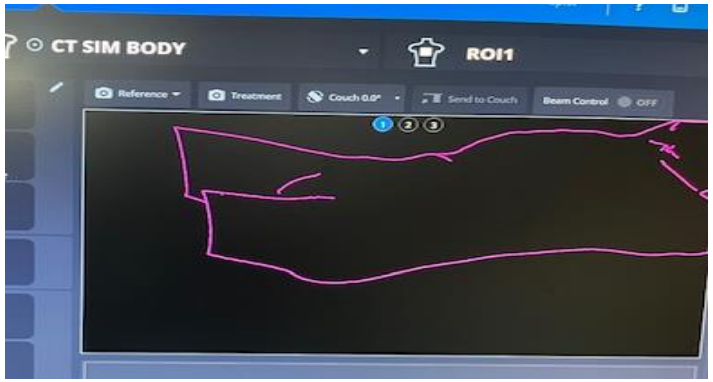
Tattoo-less patient set up

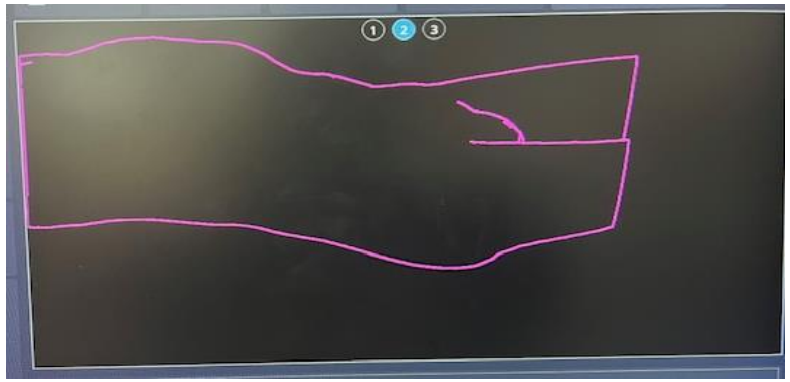
- Position the patient on the planned immobilization(knee support/ vacloc)
- Align the patient with sagittal laser on couch
- Switch on SGRT cameras
- Move couch till all 6D values come within threshold limits
- Move the patient if needed to achieve alignment (Postural video)

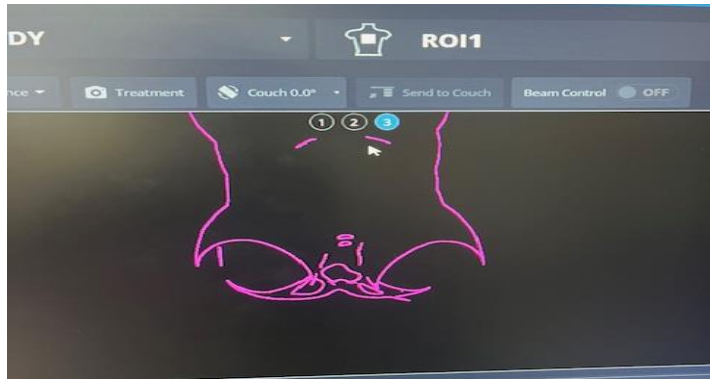
Why SGRT for Pelvic targets?

- **Tracking Patient Movement -** Pelvic cancer patients can experience motion due to changes in the bladder, bowel, or even slight body movements.
- **Improved Comfort and less invasive techniques -** Traditional immobilisation techniques such as a rigid molds or devices, can be uncomfortable for the patient and potentially cause anxiety.

Multi –Angle Real- time view

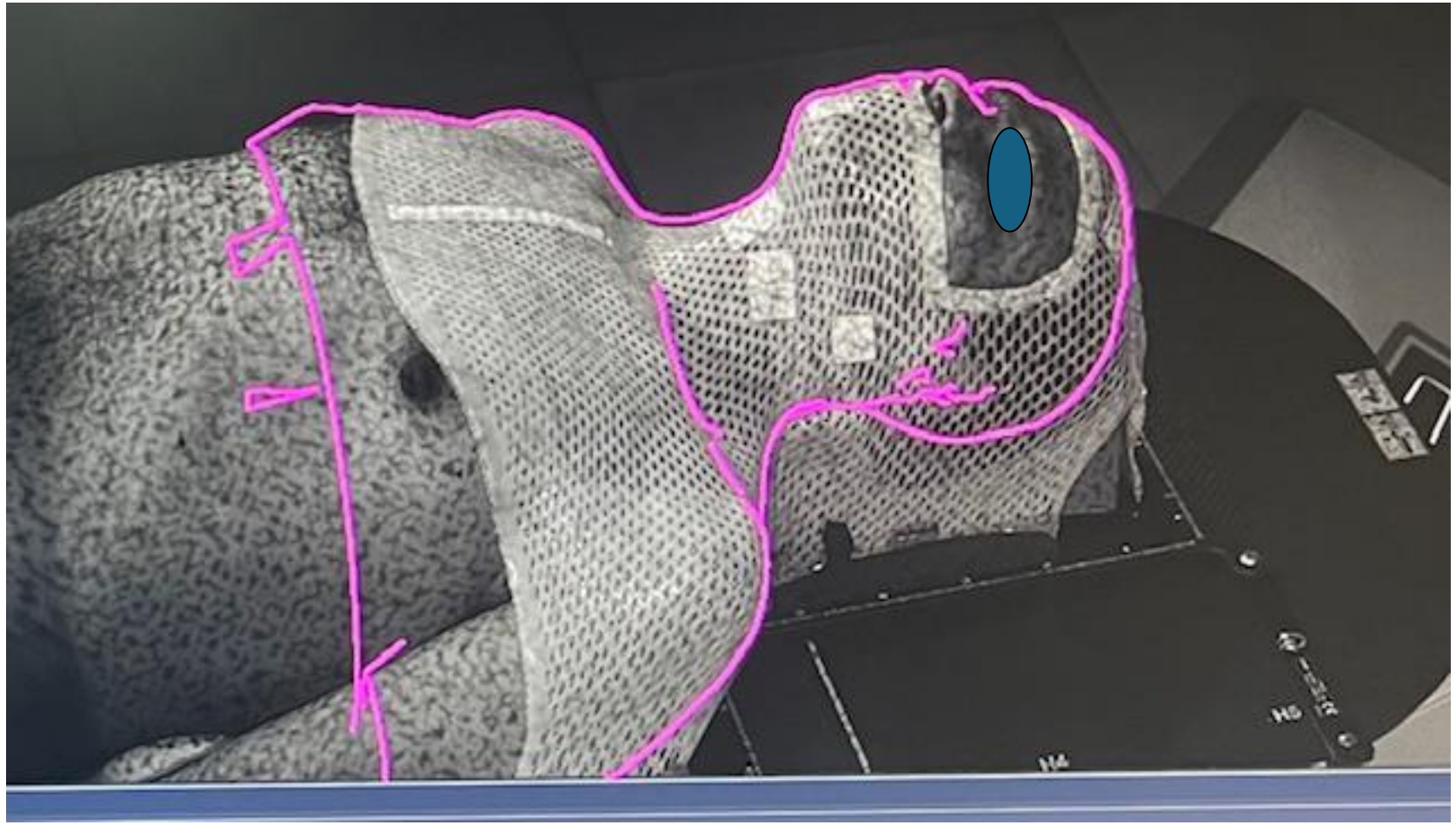






✓Though **internal organ motion**(e.g, bladder or rectum filling) still requires IGRT, SGRT helps detect **external motion** (e.g, pelvic tilt, breathing –related shifts).

Optimising Patient Experience in head Neck radiotherapy



Reasons for adopting SGRT in Head and Neck

- **Patient Positioning:**
  - ✓Traditionally, patient positioning adjustments have been made by aligning surface marks on thermoplastic masks.
  - ✓Neck area can be monitored for swallowing, without relying on patients to do it.
- **Patient Experience:**
  - ✓Head and Neck patients consider masks to be both helpful and a source of stress.
  - ✓Approaches to assist patients experiencing claustrophobia.
- **Limitations in Intra- fraction, monitoring:**
  - ✓Routine daily CBCT is not needed.

Time of Simulation

✓Cut the mask in the facial region and laterally up to the **tragus** region.

✓**Inspect the cut edges** for sharpness. If any are found ,apply micropore tape to prevent injury.

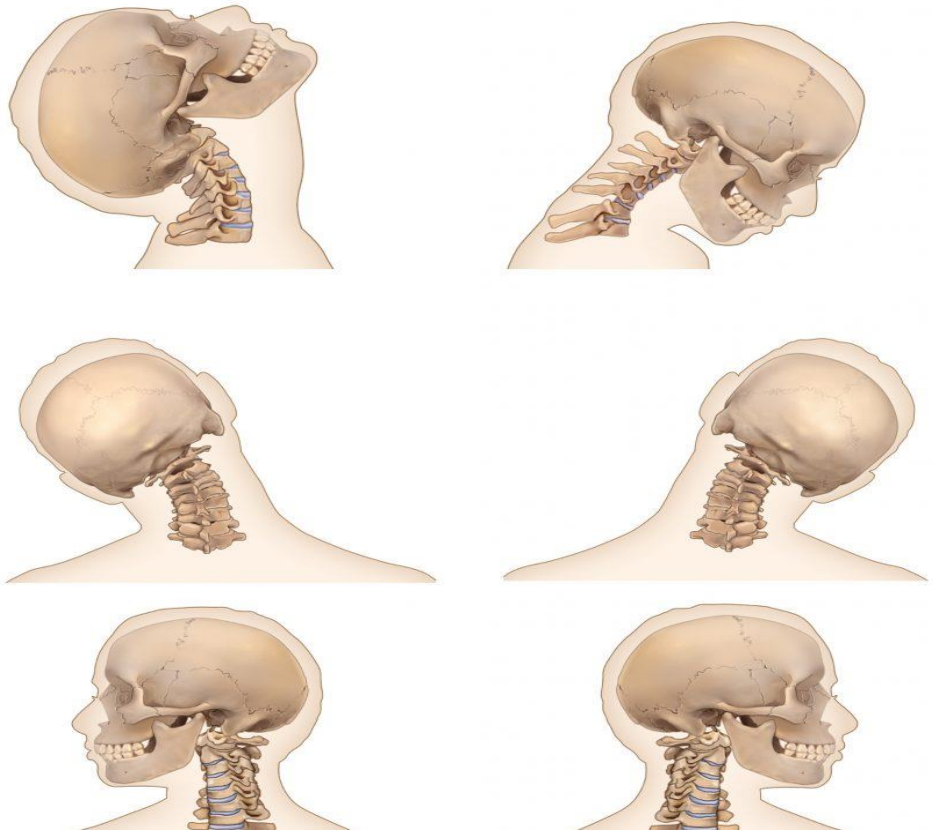
Treatment workflow

- Patient lies on Couch,rests in head – cup sponge
- RTTs set couch coordinates
- Turn on AlignRT
- Move patient head/shoulders into position with deltas

  & postural video
- Put on mask
- Move head to Align rotational deltas(pitch,roll,rotation)
- Shift table to get translational deltas into tolerance(3mm/2deg)

Impact on Rotations

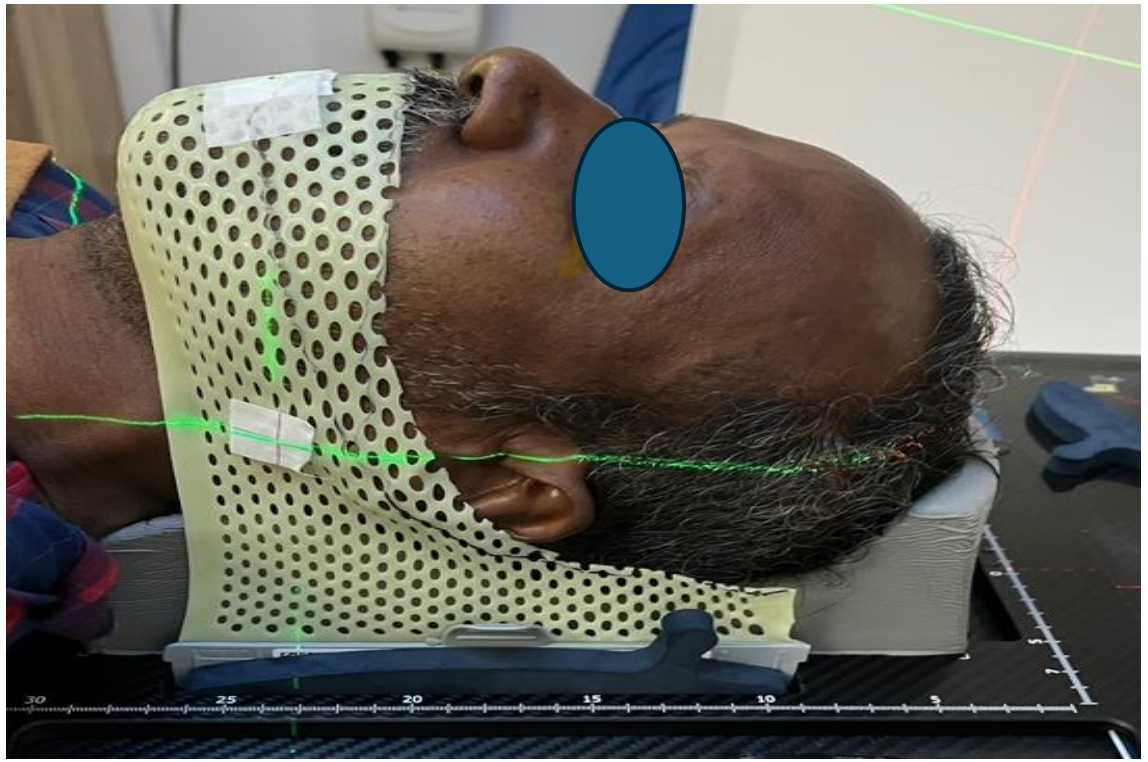
- Correct rotations before imaging
- Neck Flexion and Shoulder position
- Reduces the need for re-setup



Impact on Time

- Reduction in multiple re-setups
- Patient in mask for lesser duration
- Potential for reduced imaging time

CHIN STRAP FOR WBRT



Benefits to Patients

- Lowers patient anxiety helping them to focus on their rest and healing
- No visible marks for others to inquire about
- No constant reminder of hardship they are enduring
- Offers a worry free treatment. Patients can continue hobbies such as swimming and exercising
- Great option for patients who are allergic or sensitive to adhesive
- No re-scans or additional imaging due to lost marks
- Lesser radiation imaging dose

Staff Feedback

- **Quality of the Patient set up**
  - ✓ Surface setup allows the RTTs to see the full body when positioning the patients
- **Improved Work-flow**
  - ✓ Reducing setup time and enabling efficient patient positioning allows staff to focus on other aspects of patient care (Average time for DIBH treatment with SGRT is around 10-12 mins)
- **Confidence**
  - ✓ Gives more confidence that leads to enhanced patient care and overall job satisfaction among staff members
- **Reduced Physical Strain**
  - ✓ Automated positioning and monitoring capabilities reduces the physical strain on staff
- **Efficiency**
  - ✓ Reduces repeat imaging procedures, excess manoeuvring and skin manipulation
  - ✓ Simplifies setup procedures

Other Benefits

- **Infection control**
  - ✓No shared paint pens
  - ✓Eliminates damage to skin from sticker removal

- **Costs**
  - ✓Eliminates Purchase of Paint pens and stickers

Some Patient Responses

"The open face mask gave me a sense of control and comfort during treatment.without that option ,im not sure I would've been able to get through it.

"Having more options for my treatment made me feel significantly more in control and actively in the process"

"Struggling with anxiety and claustrophobia made the treatment feel extremely overwhelming,but the use of open face masks made a tremendous difference."

Patients' Perspective

"Many patients report feeling uncomfortable or self conscious about their appearance due to these tattoos,which can negatively affect self esteem and lead to changes in clothing habits to hide the marks ."

"Getting tattooed really emphasized that sense of losing control .i know they're just a few tiny dots in the grand scheme of things,but they serve as a daily physical reminder that I had stage 3 cancer."

"There are reminders of moments i`d prefer to forget they constantly bring back memories of the treatment and traumatic period."

Challenges

- **Patient**
  - Unusual anatomy or Obesity and skin condition
  - Claustrophobia
  - Language Barriers with patients

- **Technical**
  - Soft interlocks necessitating restart of the system at times
  - Integration with other systems

Current Studies

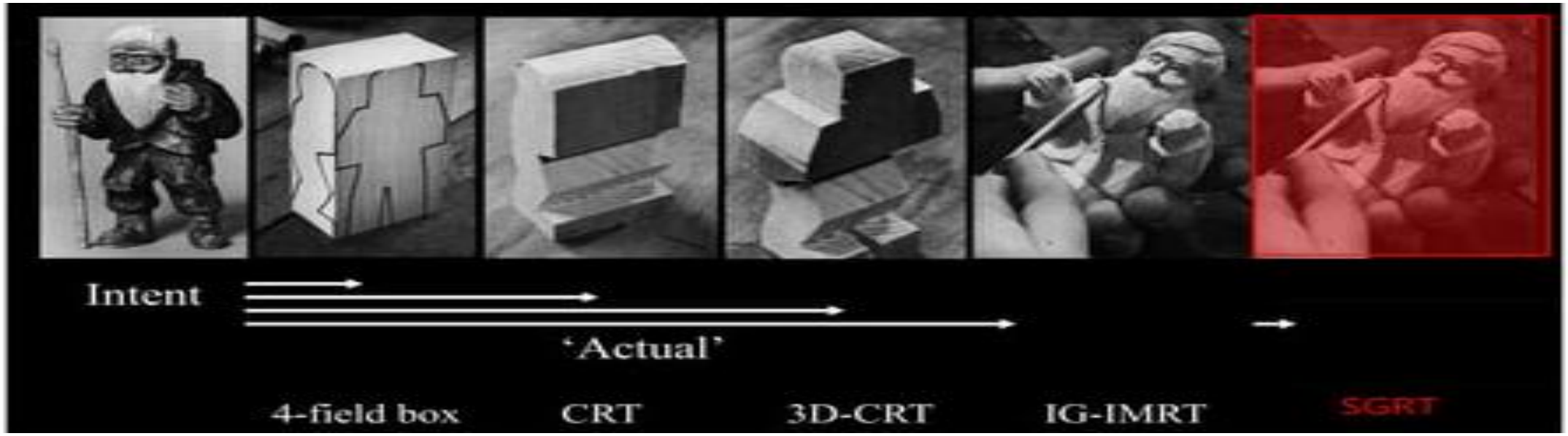
- A prospective observational study assessing the accuracy of SGRT versus tattooing in patient set-up for radiation therapy in pelvic malignancies

- Feasibility of open face mask real time monitoring for Head and Neck radiotherapy patients

- Tattoo-Less setup feasible for Breast and Abdomen treatment

Future?

- Expansion to more sites
- 100% Open Faced
- Tattoo, mask and mark free one day?



Thank You For Your Gracious Attention!

"NOT TO BE SERVED BUT TO SERVE"-

CMC Vellore motto means

Surface guided radiation therapy

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Position verification prior to RT

Position verification is a must for precision radiation treatments

What is the gold standard?

- Imaging at the treatment machine IGRT
  - 2D- EPID/ On board imaging
  - 3D- cone beam CT
  - MRI on MR Linacs
- Respiratory programmed monitoring

Are available [illegible] adequate for [illegible] verification?

NO

What do we not do routinely in position verification?

Intrafraction monitoring

SGRT

Additional tool for position verification

-improves positional accuracy

-Can give real time errors

-Both translational and rotational errors (6D)

-Intrafraction monitoring

-Motion monitoring - DIBH

-Useful on days when we don’t image the patient prior to treatment

Four eyes principle

(Freislederer et al)

{Radiation Oncology2020 (London, England), 15}

“Independent observer” in the room

(Al-Hallaq et al)

21% of these errors could have been prevented with SGRT

{Radiother Oncol 2021;163: 229–36}

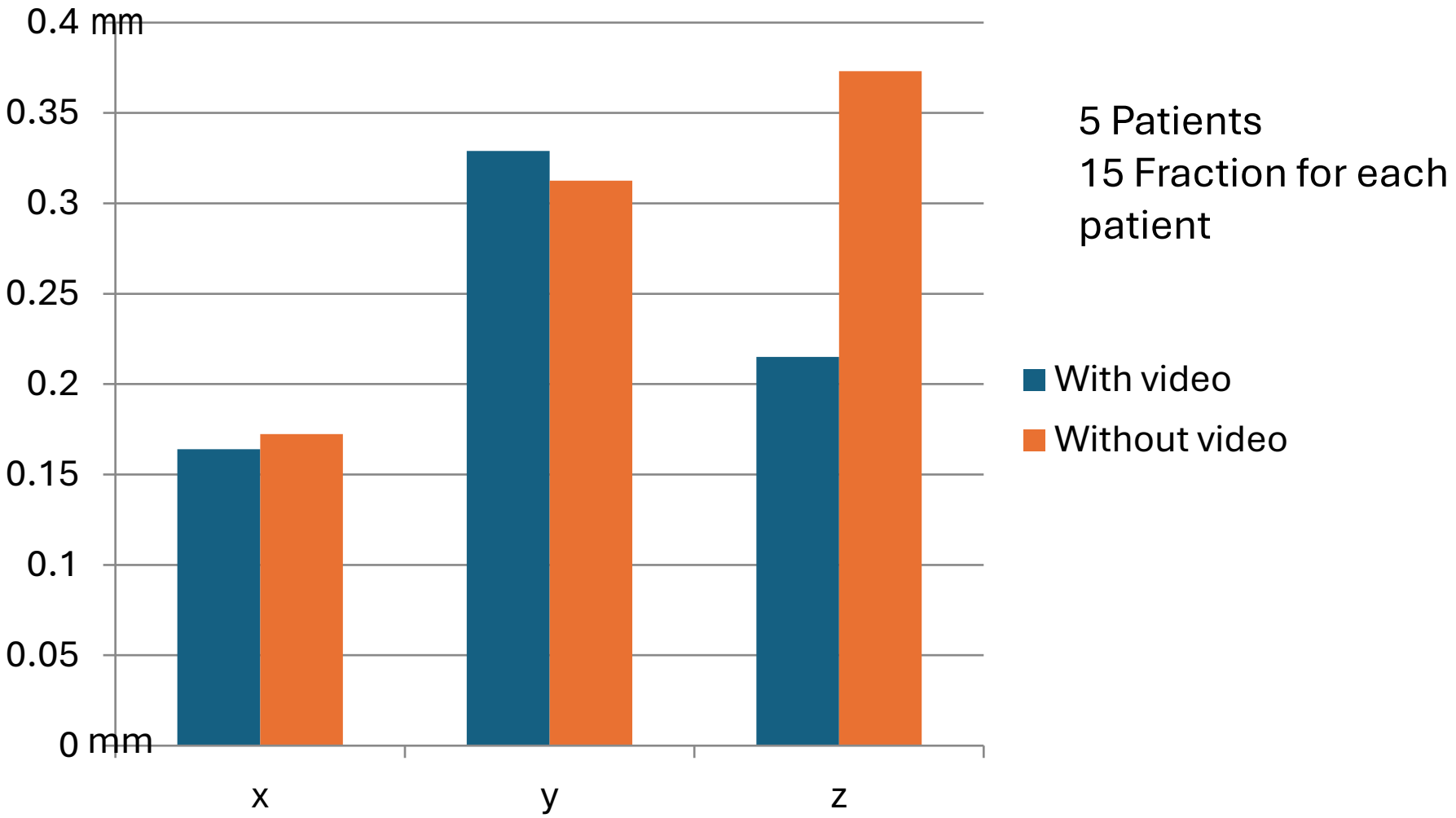
Can we write off imaging for position verification?

NO … NOT AT ALL

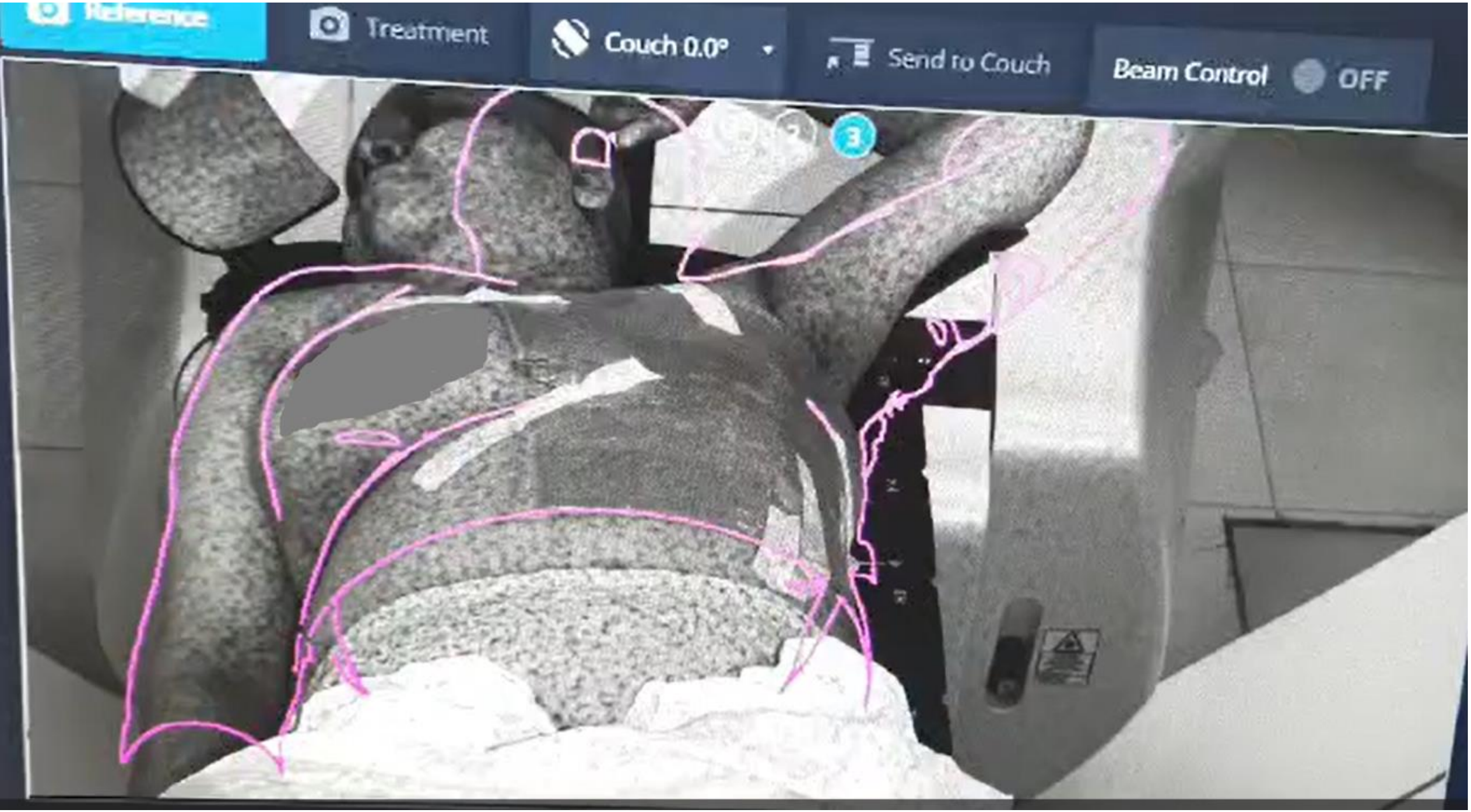
gold standard still is IGRT

SGRT can help reduce the no. of imaging

OBI Shift

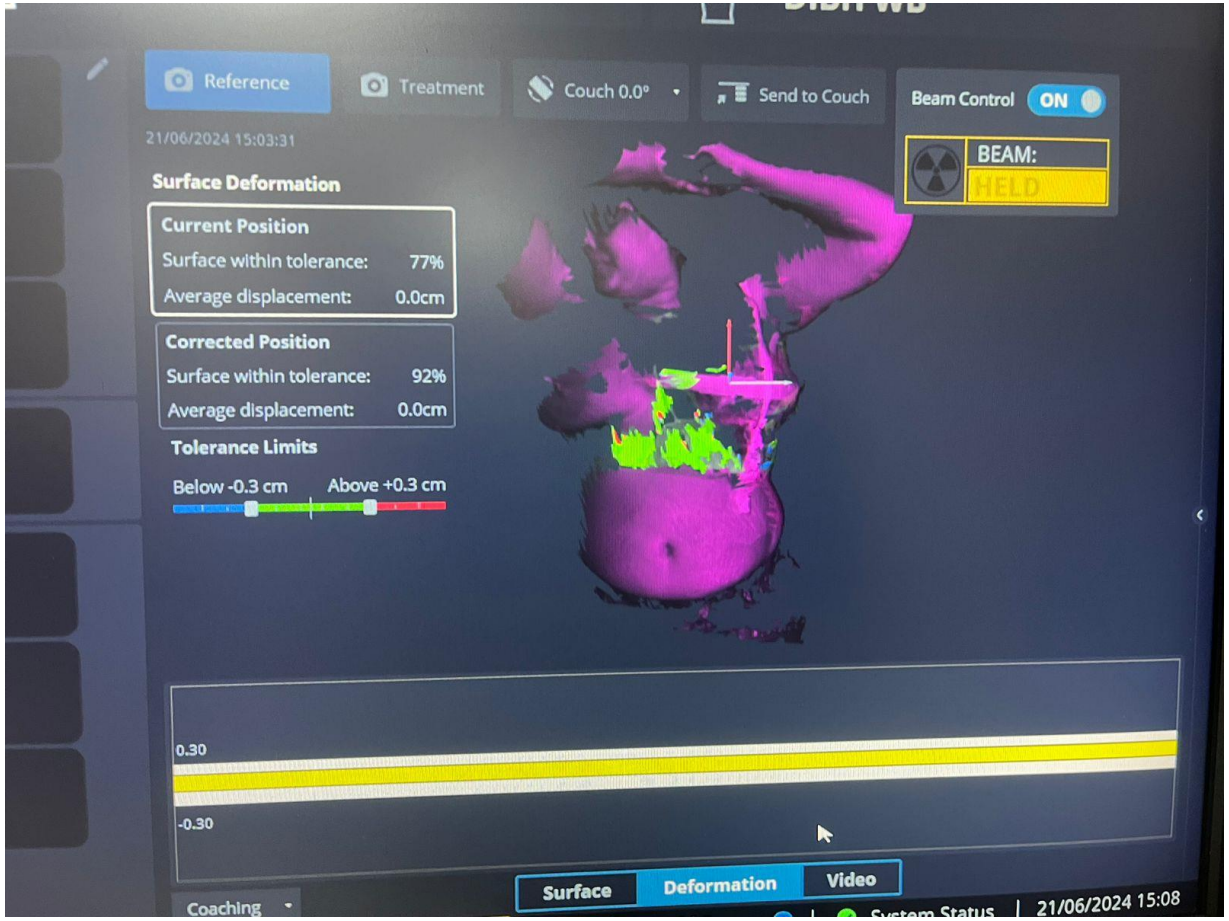

0.4 mm
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0 mm
x
y
z
5 Patients
15 Fraction for each patient
With video
Without video

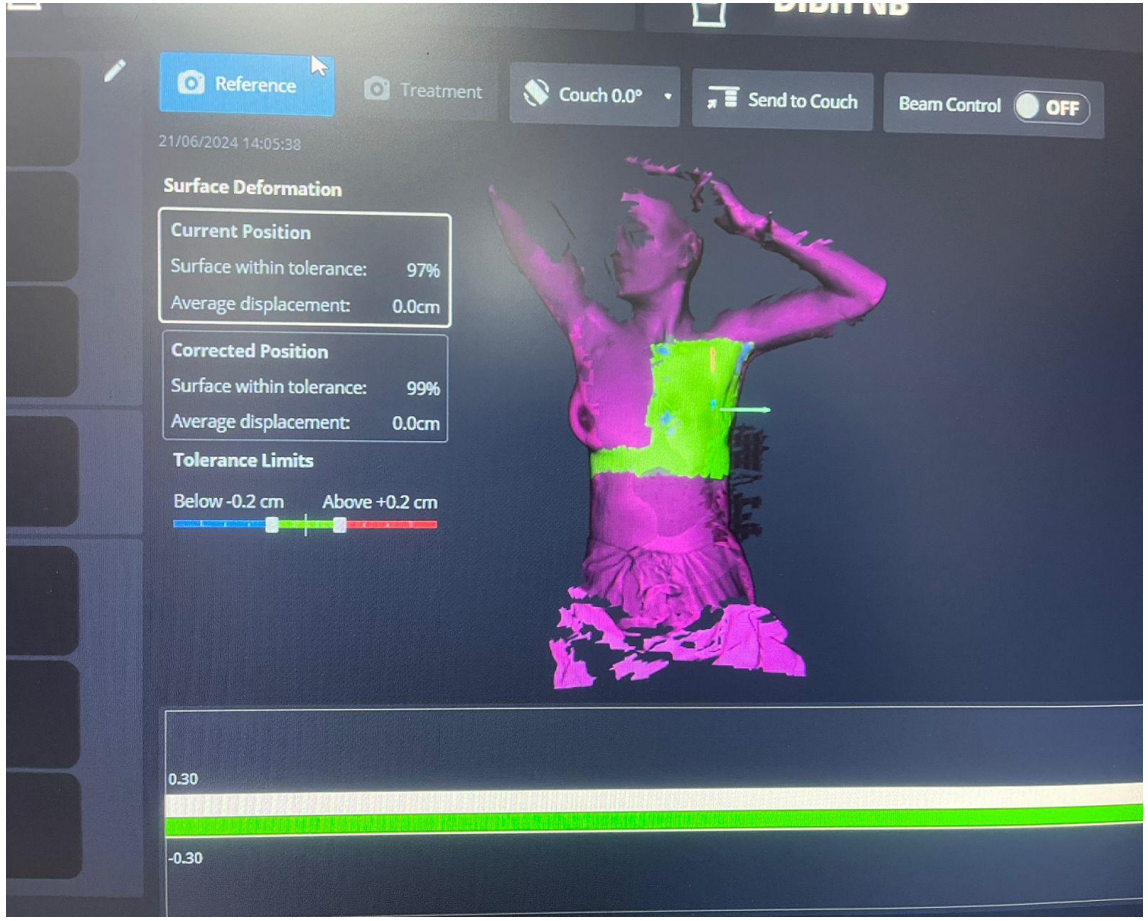
Arm position



Postural video

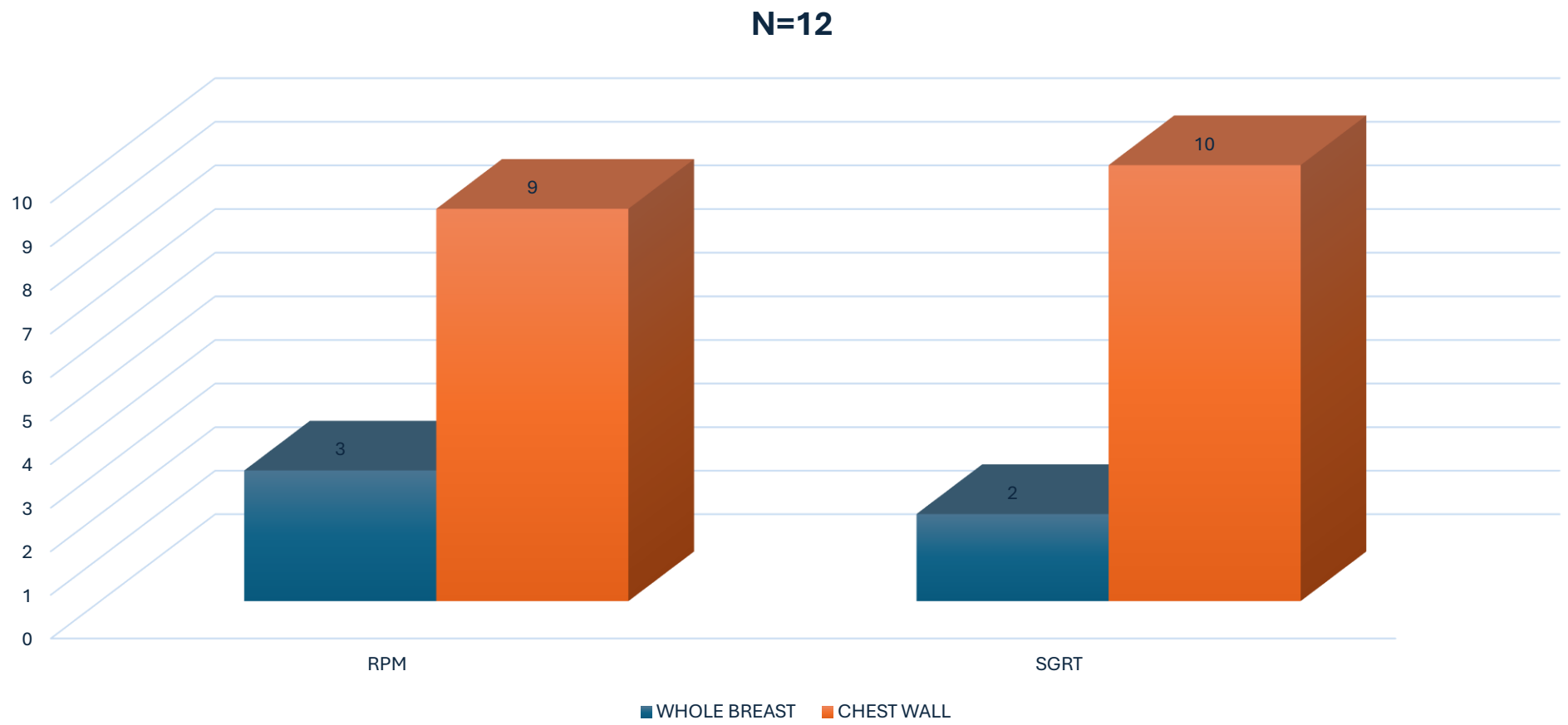
Deformation capture



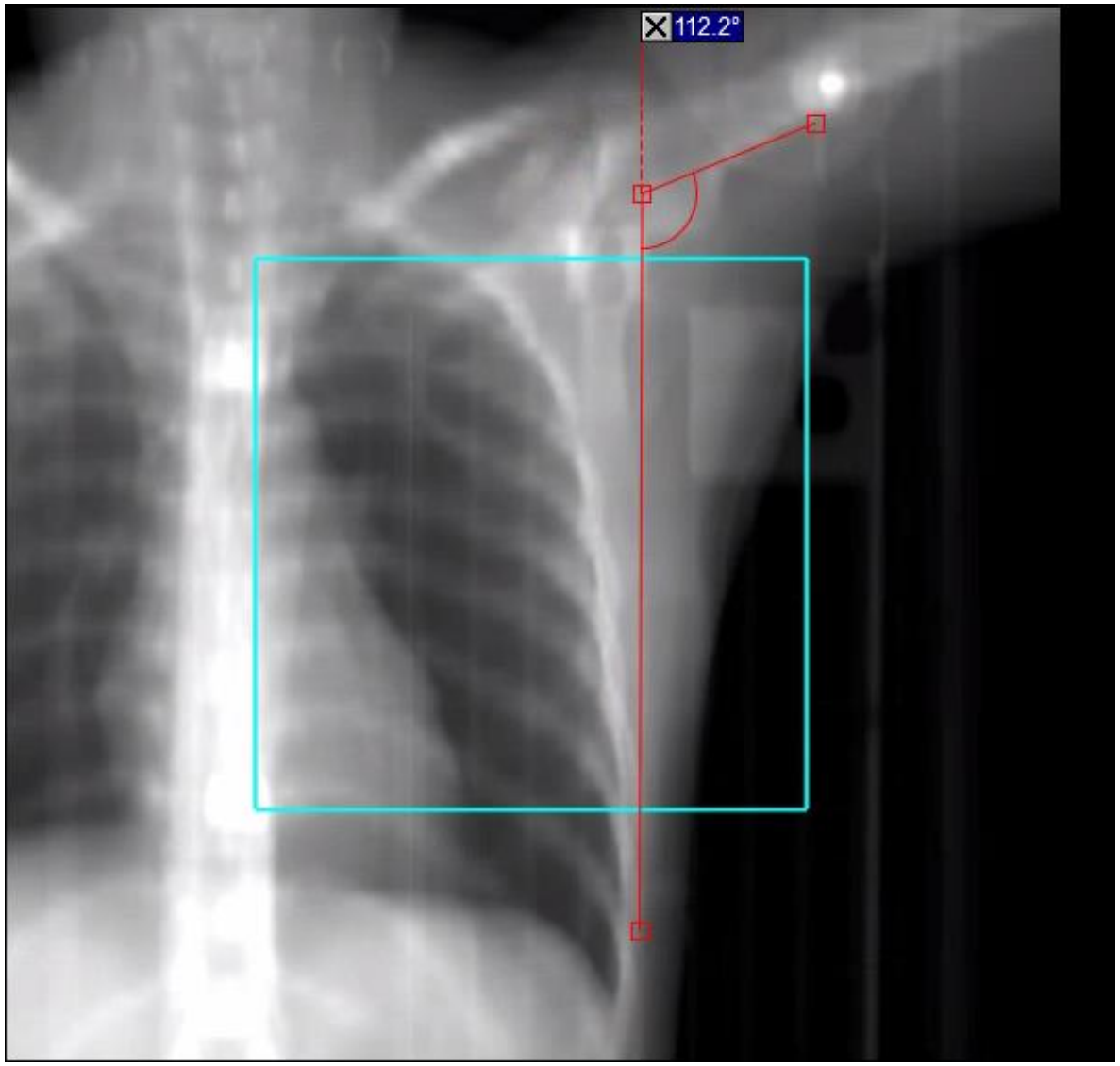


Comparison study DIBH: RPM Vs SGRT

CW vs Whole breast



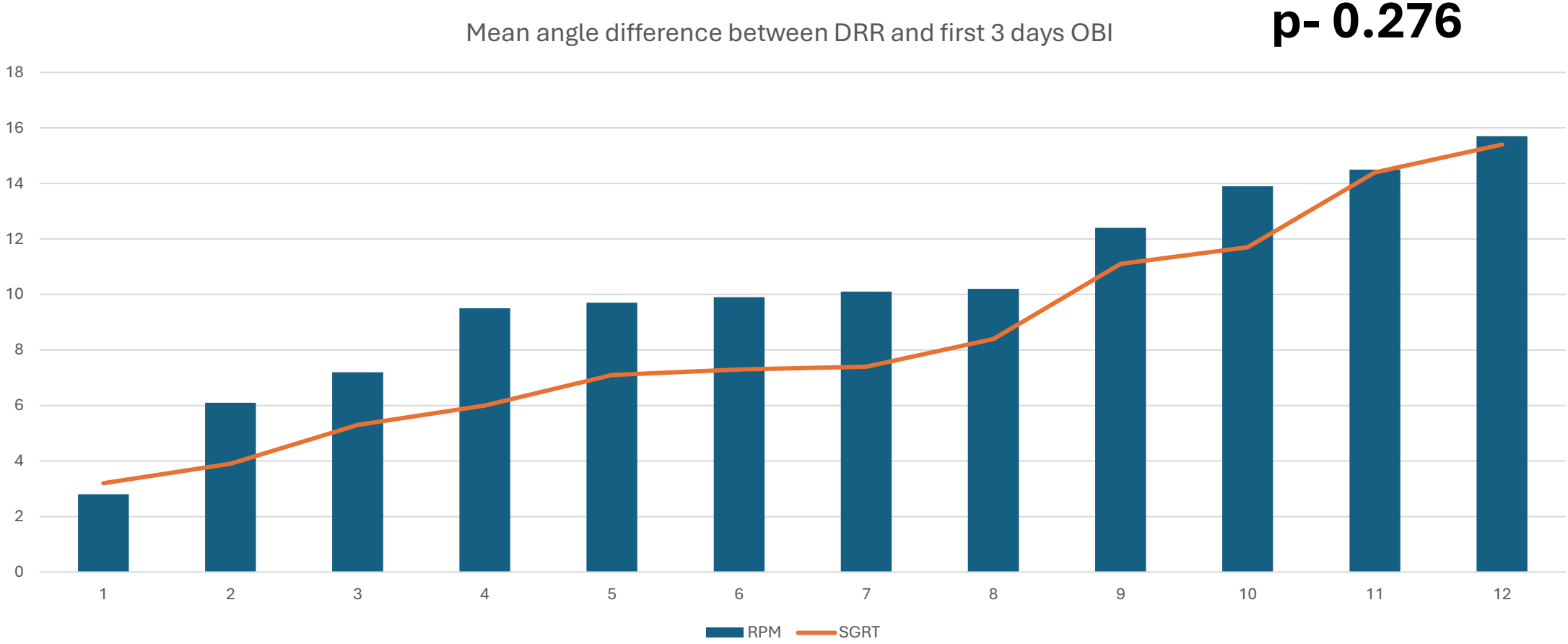
Angle between chest wall & humerus



Angle between chest wall & humerus

Independent t test

p- 0.276



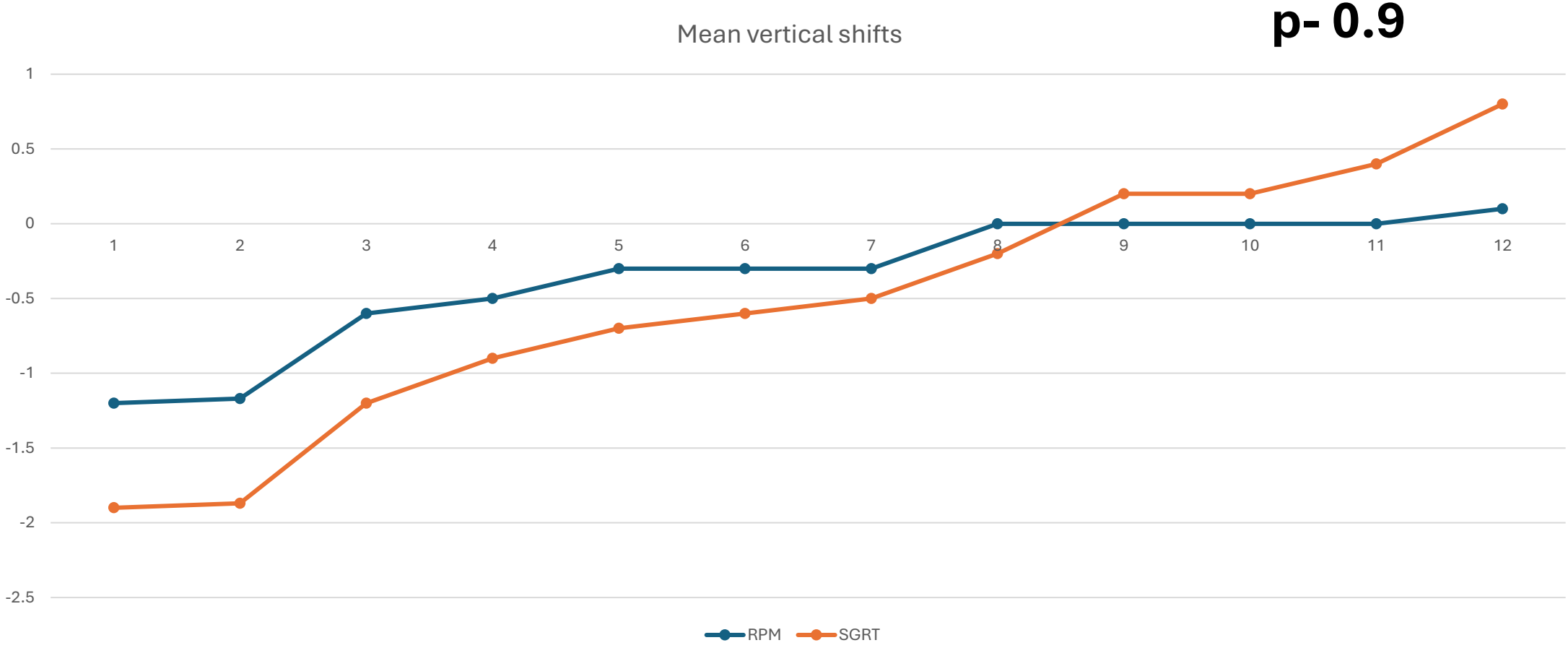
RPM: 10.1 ± 3.6

SGRT: 8.4 ± 3.9

Mean vertical shifts

Independent t test

p- 0.9



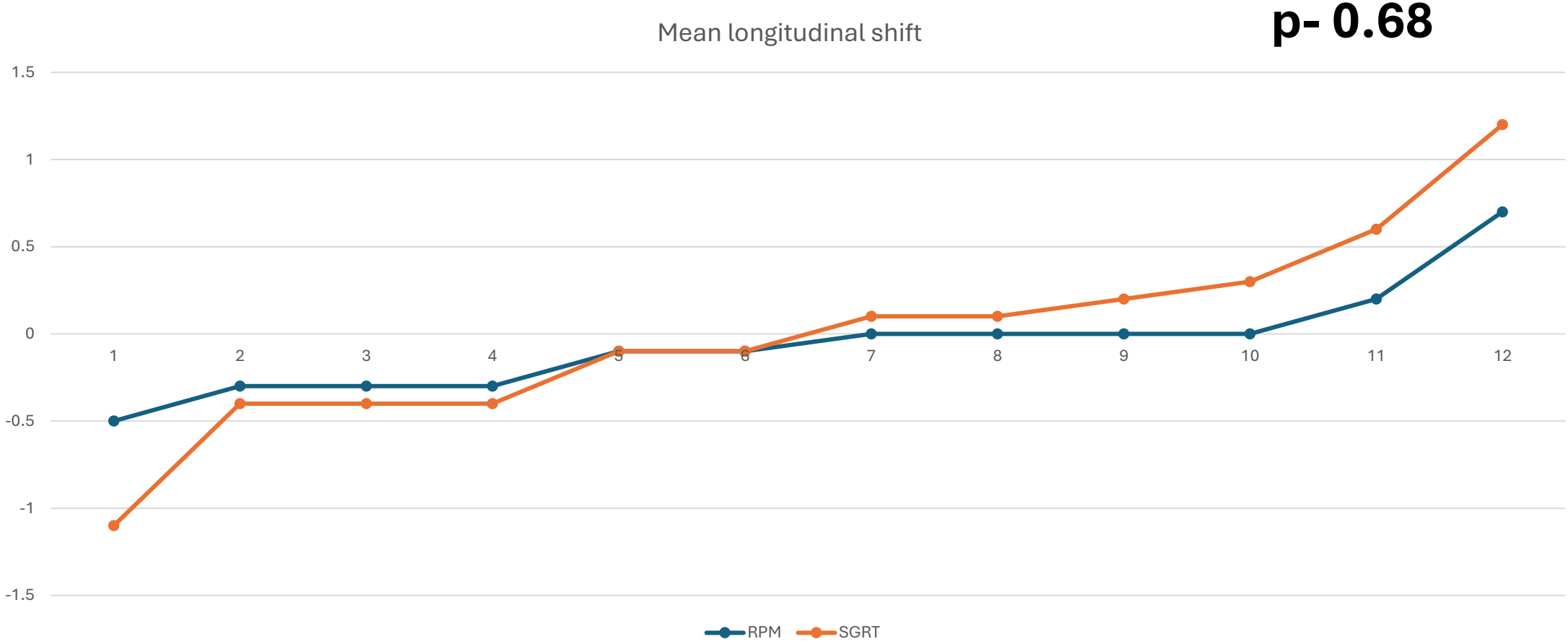
RPM: 0.48 ± 0.36

SGRT: 0.49 ± 0.20

Mean longitudinal shifts

Independent t test

p- 0.68



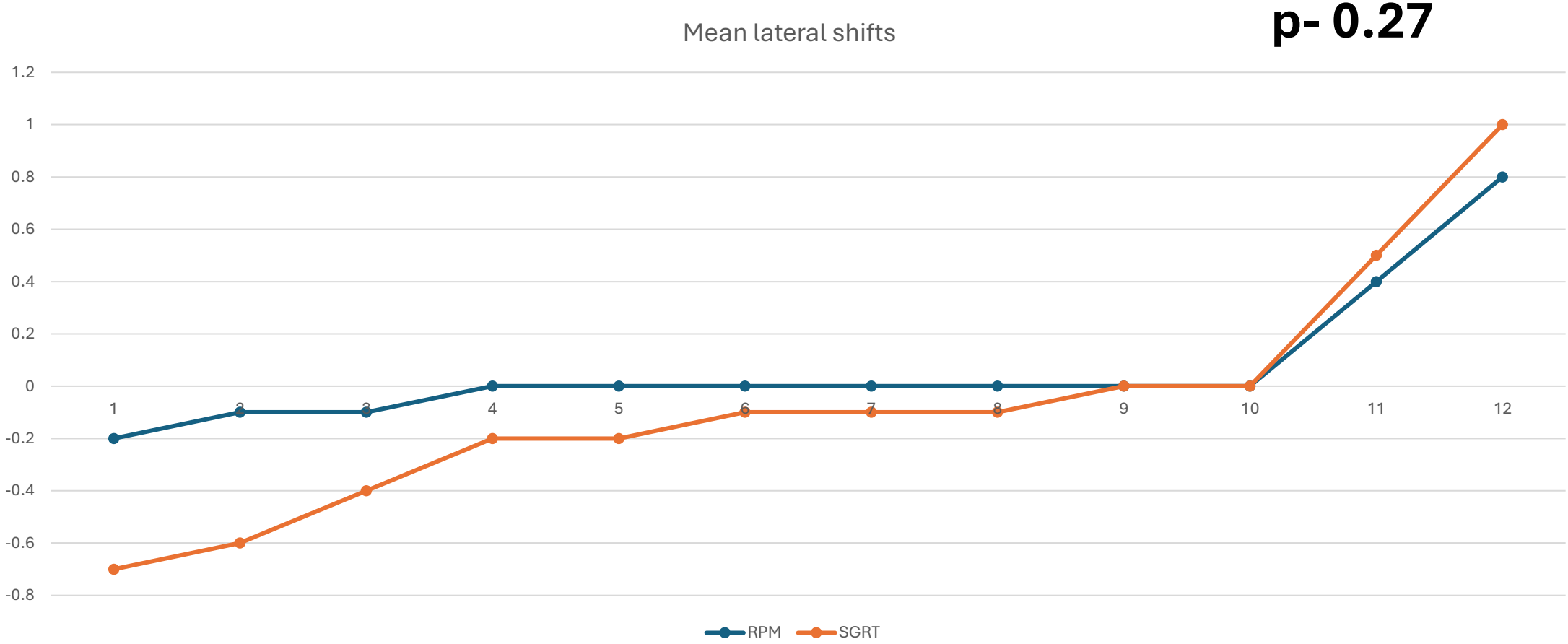
RPM: 0.32 ± 0.2

SGRT: 0.36 ± 0.17

Mean lateral shifts

Independent t test

p- 0.27



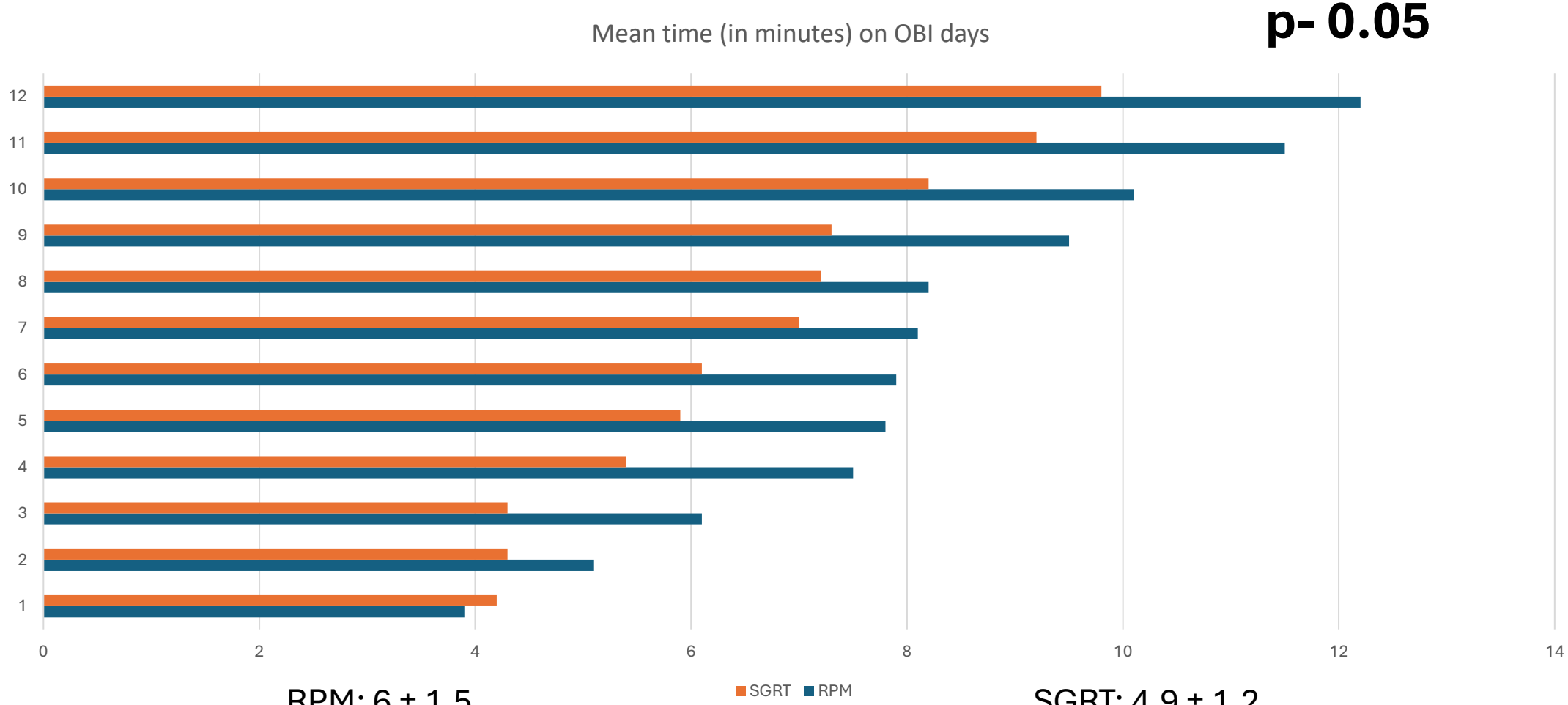
RPM: 0.23 ± 0.22

SGRT: 0.32 ± 0.17

Mean time taken on OBI days

Independent t test

p- 0.05



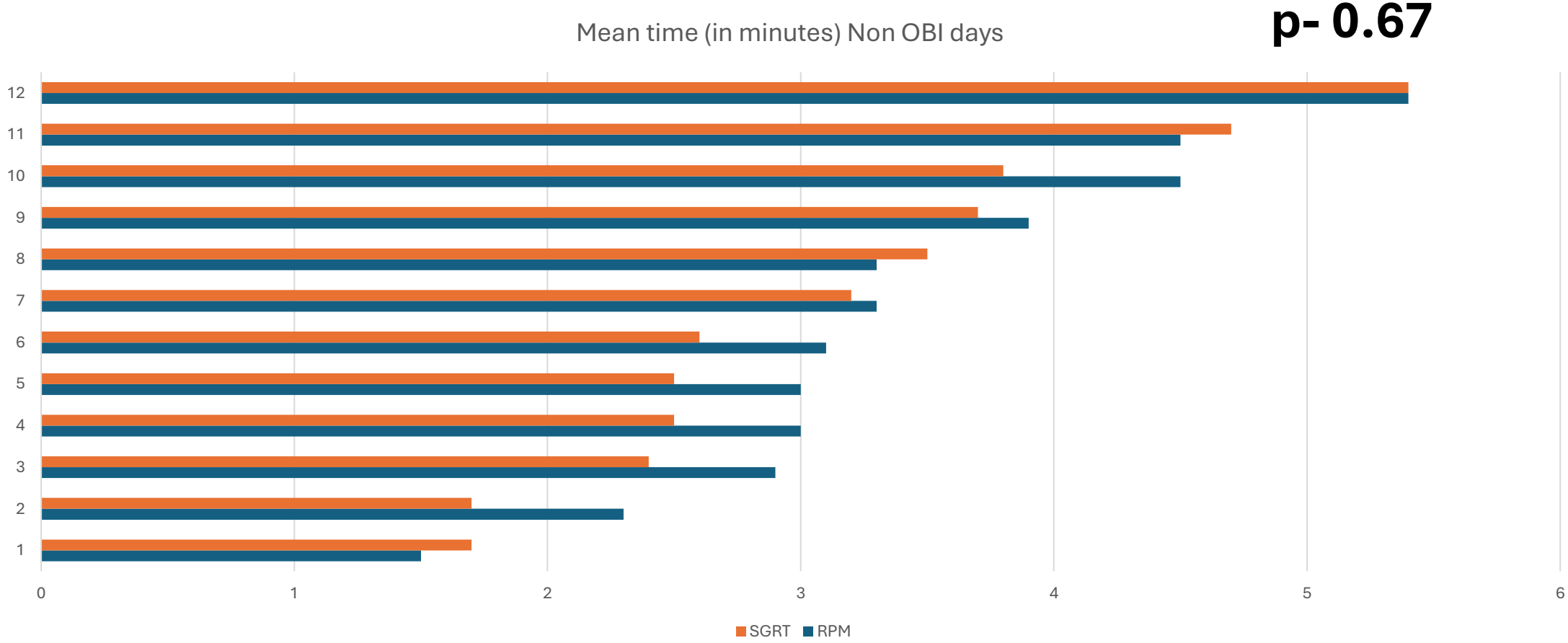
RPM: 6 ± 1.5

SGRT: 4.9 ± 1.2

Mean time – Non OBI days

Independent t test

p- 0.67



RPM: 4.3 ± 1

SGRT: 3.6 ± 0.9

- ❑A prospective observational study assessing the accuracy of SGRT versus tattooing in patient set-up for radiation therapy in pelvic malignancies

- ❑ Feasibility of open face mask real time monitoring for Head and Neck radiotherapy patients

- ❑A prospective observational study assessing the accuracy of SGRT versus tattooing in patient set-up for radiation therapy in left sided breast radiotherapy in DIBH

Other advantages

Margin of threshold of breathhold is ± 0.5 cm but its tighter in SGRT ± 0.3 cm

If the patient lifts the back/ arches the back to match up with the breath hold threshold instead of true breath hold, this can be detected on AlignRT as it gives the rotational error (pitch)

Patient comfort is enhanced (no marks on the body)

Advantages…

Intrafraction monitoring of position possible with AlignRT

Lesser use of OBI (lesser radiation exposure)

Gross errors can be picked up immediately (breathing/ swallowing /coughing) and the beam will be stopped

Challenges we face

- Not suitable for all patients (darker skin tone, body hair, large abdomen- light attenuating surfaces)
- Phobia (colored light)
- Influenced by ambient light (over illumination or uneven illumination in the treatment room)
- gel bolus is not been detected by the system efficiently

- Its matching external surface (does it always match with internal?)-
  - for superficial tumors (where surface deviations can act as a surrogate for tumor motion) SGRT allows for a more accurate positioning compared to 3-point-lasers

- Gating capabilities is not robust yet except for DIBH

Challenges we face…

Technical

- Soft interlocks necessitating restart of the system at times
- Gantry position (320^0 to 40^0) interferes with data acquisition – results in signal loss (CBCT is a challenge)
- More beam-offs in SGRT (does it increase the wear& tear of the machine and reduces its longevity?)

Visual feedback for patients during DIBH is a small monitor and difficult to understand for all patients compared to RPM visual monitor

Real time coach patient monitor

Future...

- To go tattooless
- Open face mask
- Reduce PTV margin
- To determine the dose using dose RT
- Map RT – helps have more freedom of beam angles

Conclusions…

- SGRT – additional tool for position verification
- Increases the accuracy of positioning
- Reduces the need for imaging
- Able to stop the beam automatically when deviation is more than the set limits
- Intrafraction monitoring of all 6 directions on all days possible
- Noninvasive; no additional radiation exposure
- Reduces setup time

- Enhances patient comfort- tattooless, open face mask etc
- Dose RT and Map RT can improve RT planning and dose distribution

Thank you for your patient listening

"Not to be ministered unto but to minister" Mark 10:45

Our Vision

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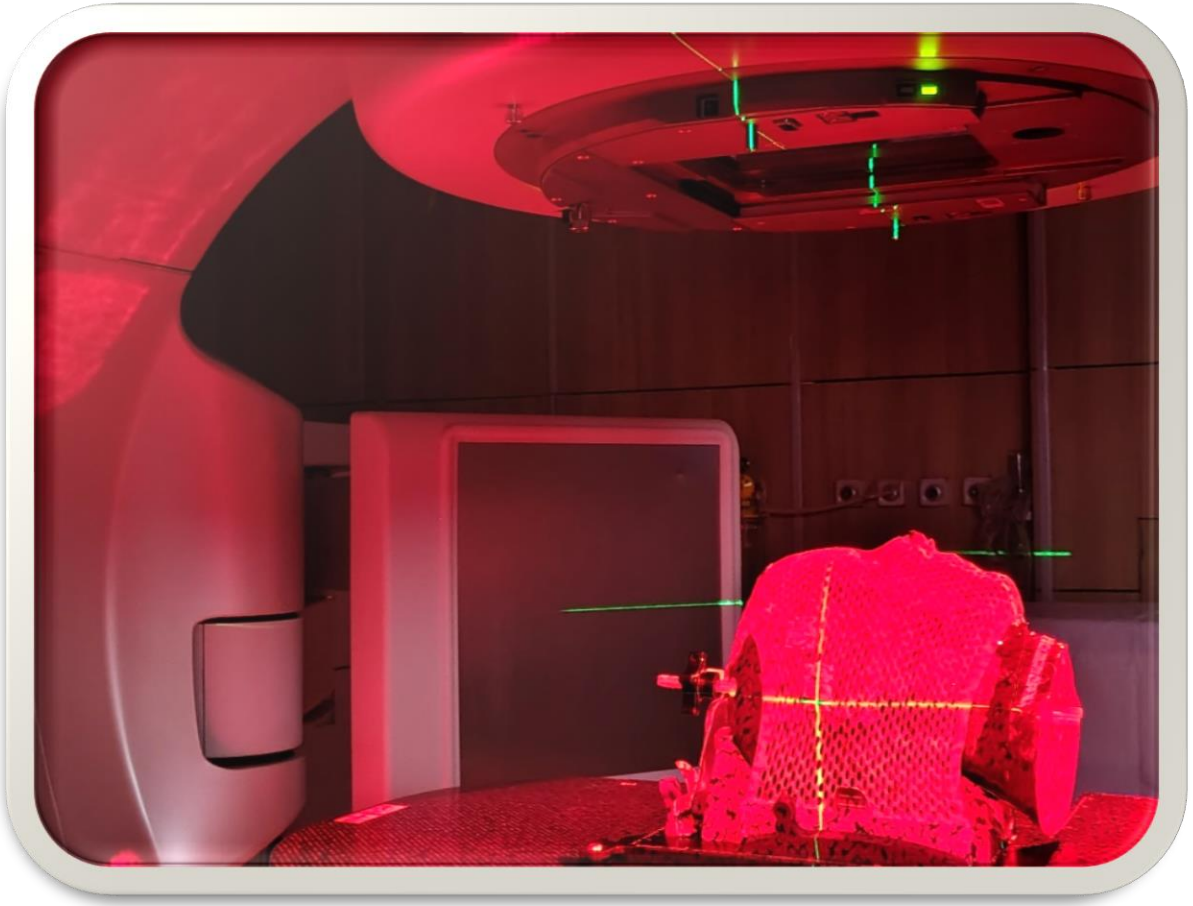
SGRT - CMC Experience

visionrt



Dr S Ebenezer Suman Babu

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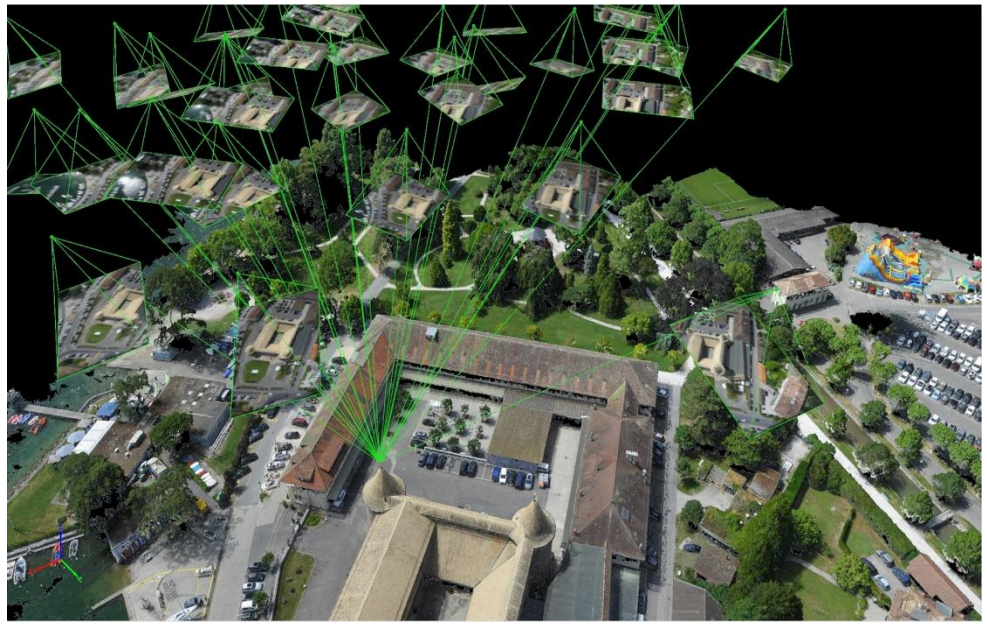
Basics of Surface Guided Radiation Therapy

- There has been a substantial growth in the use of optical cameras to determine patient external position before and during treatment.
- **The process of determining 3D information from 2D images is known as photogrammetry.**
- In this process,

  - A pseudo-random light pattern is emitted onto the patient, and

  - A camera interprets the reflection to gather the geometrical coordinates of the surface.
- Photogrammetry is a tool that has been employed in radiation therapy for the determination of patient contours.



Photogrammetry

Khan, F. M., & Gibbons, J. P. (2014). *Khan's the Physics of Radiation Therapy*. http://ci.nii.ac.jp/ncid/BB15763073

Basics of Surface Guided Radiation Therapy

- Recently, this method has been used to verify patient positioning - the system is calibrated to the linac's coordinate system so that the patient surface model can be registered to the expected reference surface.
- **The expected surface is obtained either from a previous optical image or calculated from the treatment-planning CT.**
- The camera system may be calibrated by imaging a plate with fiducials or markers positioned in a known location in the room.
- Photogrammetry may be accomplished using two or more cameras (stereophotogrammetry)
- In stereophotogrammetry, two or more images are taken at different positions to estimate the 3-D coordinates of the object.

Khan, F. M., & Gibbons, J. P. (2014). *Khan's the Physics of Radiation Therapy*. http://ci.nii.ac.jp/ncid/BB15763073

Medical Physics
The International Journal of Medical Physics Research and Practice

Stereo-photogrammetry for the determination of patient surface geometry

D. E. Velkley and G. D. Oliver, Jr.[a)]

Mallinckrodt Institute of Radiology, St. Louis, Missouri 63110
and M. S. Hershey Medical Center, The Pennsylvania State University, Hershey, Pennsylvnia 17033

(Received 11 April 1977; accepted for publication 18 December 1978)

A stereo-photographic system has been developed with which surface contours of a human subject may be obtained rapidly and objectively. Nonmetric cameras are used and the results are obtained from direct measurements of the photographs. Software has been developed for interpretation of the photographic data with the asistance of a small computer and desk-top digitizer such as those routinely used in radiotherapy treatment planning. With this system the coordinates of a point on the subject may be determined with an accuracy of ±1–2 mm.

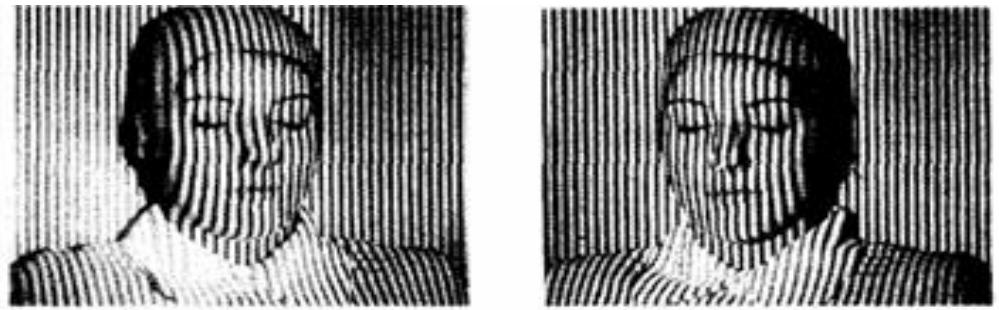


FIG. 3. Stereo-pair of photographs of subject's head with the projected pattern. A small piece of black tape has been added above each of three fiducial points on each side of the subject to make the points more recognizable.

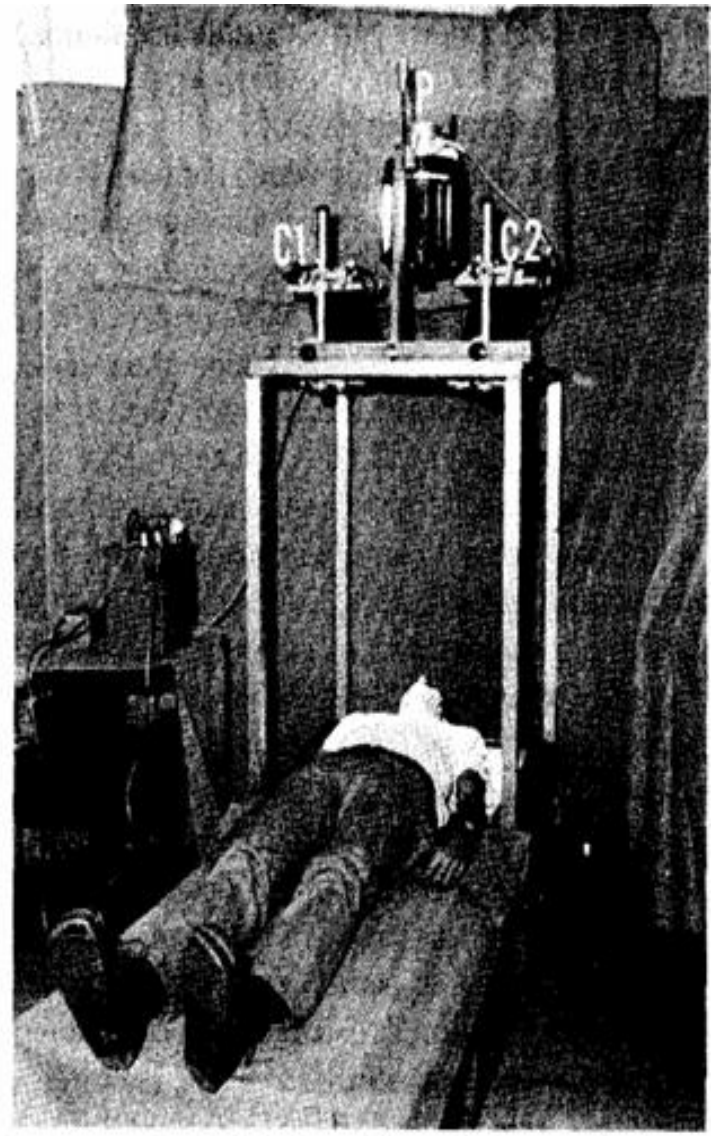
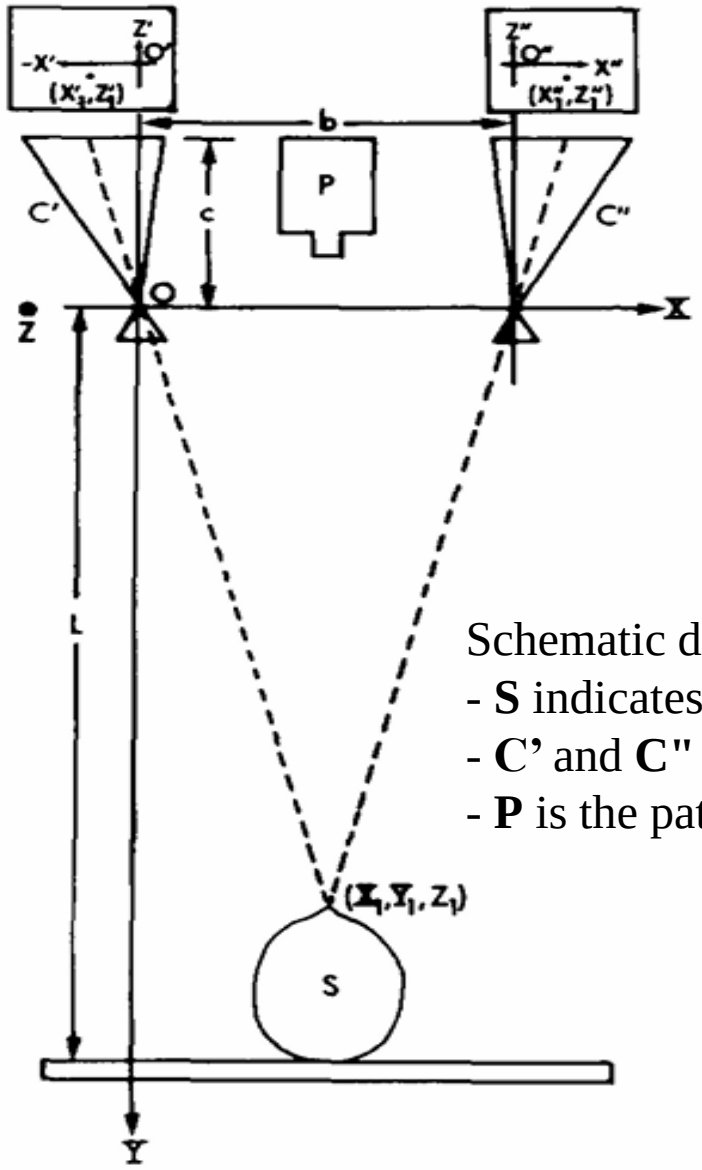


FIG. 2. Photograph of subject in position to be photographed.

Basics of Surface Guided Radiation Therapy

- With knowledge of the distance between the cameras
  - the intersection of the two lines of sight from each camera to a common point is used to triangulate the coordinates of the point.
- The common points can be obtained from either fiducials or projected light.
- Because the skin does not typically have enough variations to triangulate many individual points
  - a structured light pattern is projected onto the skin to allow the cameras the ability to identify many common points over the surface area of interest.

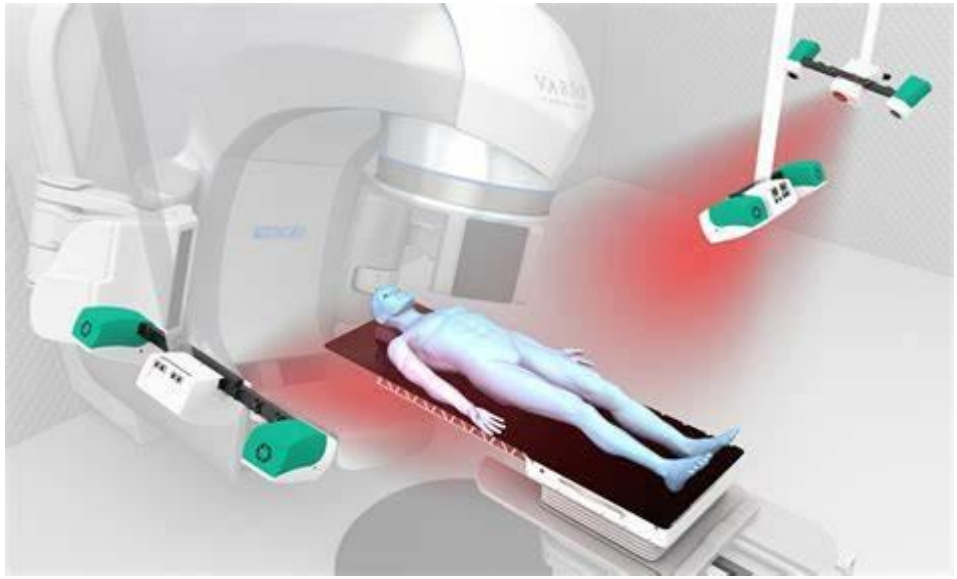


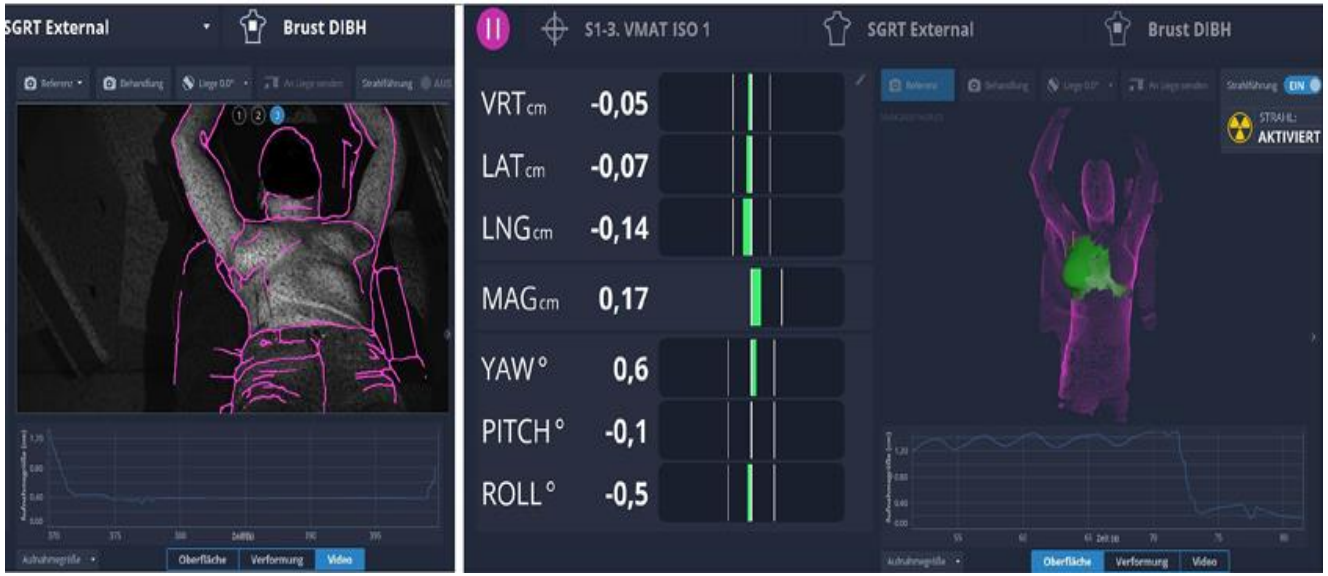
Schematic diagram:
- **S** indicates the subject.
- **C'** and **C"** are the two cameras
- **P** is the pattern projector

Khan, F. M., & Gibbons, J. P. (2014). *Khan's the Physics of Radiation Therapy*. http://ci.nii.ac.jp/ncid/BB15763073

Basics of Surface Guided Radiation Therapyv

- Stereophotogrammetry is employed in the AlignRT system (VisionRT, London, UK). In this system
- Three imaging pods are mounted on the ceiling out of the range of the gantry rotation.
- Each pod contains two charge-coupled device cameras, and a speckled-light projector used to obtain surface topology information.



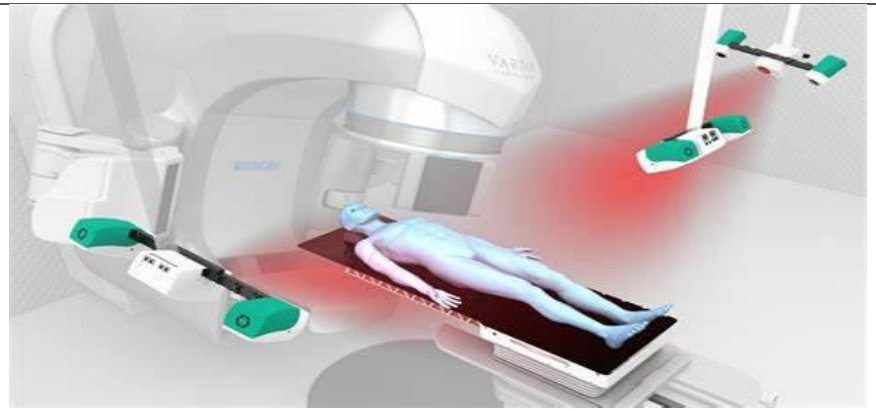


https://www.iof.fraunhofer.de/en/competences/imaging-sensing.html

Freislederer et al. Radiation Oncology (2020) 15:187
https://doi.org/10.1186/s13014-020-01629-w

Basics of Surface Guided Radiation Therapy

- After the patient is placed in the treatment position, a near-infrared (IR) structured light pattern is projected onto the patient surface, which the stereo cameras image to create a high-resolution 3-D map (~20,000 points) of the patient's surface.
- The obtained surface map is compared with a baseline reference map using a rigid-body registration process.
- Phantom tests of this system have demonstrated an accuracy of better than 0.5 mm in both the surface model itself and its positional accuracy.



https://www.iof.fraunhofer.de/en/competences/imaging-sensing.html

Freislederer et al. Radiation Oncology (2020) 15:187
https://doi.org/10.1186/s13014-020-01629-w

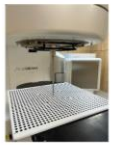
Quality Assurance – SOP…Calibration check (Daily)

Steps

Vision RT Daily QA

Setup:

1. Align the Calibration Plate at isocentre (SSD 100cm)
2. Align it with the Light field cross-wire
3. Orient the plate correctly towards the Gantry (dots 1 and 4 towards Gantry)
4. Ensure all the lights are ON replicating the lighting conditions during Patient Treatment
5. Remove any items blocking the cameras



Calibration Check:

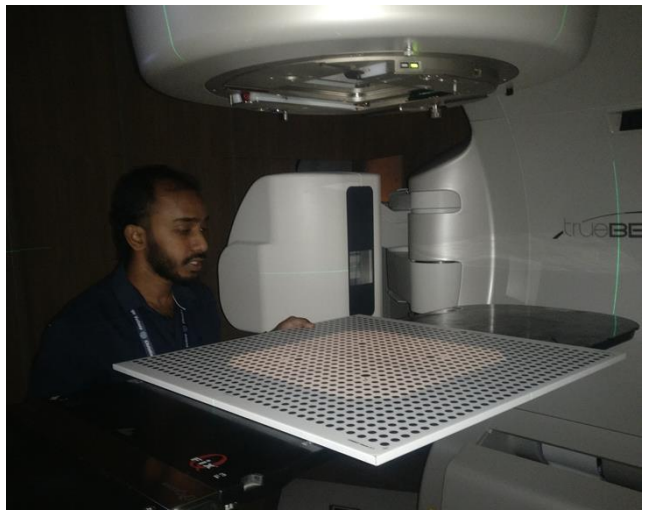
1. Open **Align RT** Application
2. Select the **Daily QA** module
3. After making sure setup is right click **Start Daily QA**
4. Ensure values are within a Tolerance level of 1mm
5. Click **Done**

Tolerance

0.6 mm is warning level

1mm indicates that re-calibration should be done

Setup



Quality Assurance – SOP…Cube Calibration (Weekly)

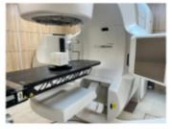
Steps

1. Select **System Calibration** module in the Align RT platform

2. Initialize Plate Calibration to check calibration

Setup:

Set the Calibration Plate at SSD 100cm
Align the Anterior and Lateral Lasers with the cross-wire
Cross verify the alignment with Light Cross-wire
Make sure all the lights are ON as if during Patient Treatment



If Calibration check values are high, use advanced camera operations to mark the marker (1,2,3,4)on the calibration plate.

3.Initialize Cube Calibration

1. Position the Cube with laser intersections and cross verify with cross-wire as shown in figure (Ensure Rails are at extreme ends)
2. Load the plan "**Vision RT QA**" in the treatment console
3. Acquire the MV images in all four Gantry angles
4. Export-> to "MV Images for calibration_Align RT" from Image Browser (Make sure previous images are deleted before exporting)
5. Cut/Copy the Exported images from **This PC->Network shared folder-> "MV Images for calibration_Align RT"**
6. Paste in **F drive** folder named **VRT** under **MV Image folder ("VRT (F:)/MV Image")**
7. Make sure Gantry angle is 0° and Imaging arms are retracted, Before Clicking **Continue**
8. Click **continue** on Vision RT System to check calibration
9. Click **Re-Calibrate -> Continue**
10. In the pop up window where it asks, "Would you like to verify the camera update?", click **"No"**
11. Repeat Plate Calibration Click **Done**

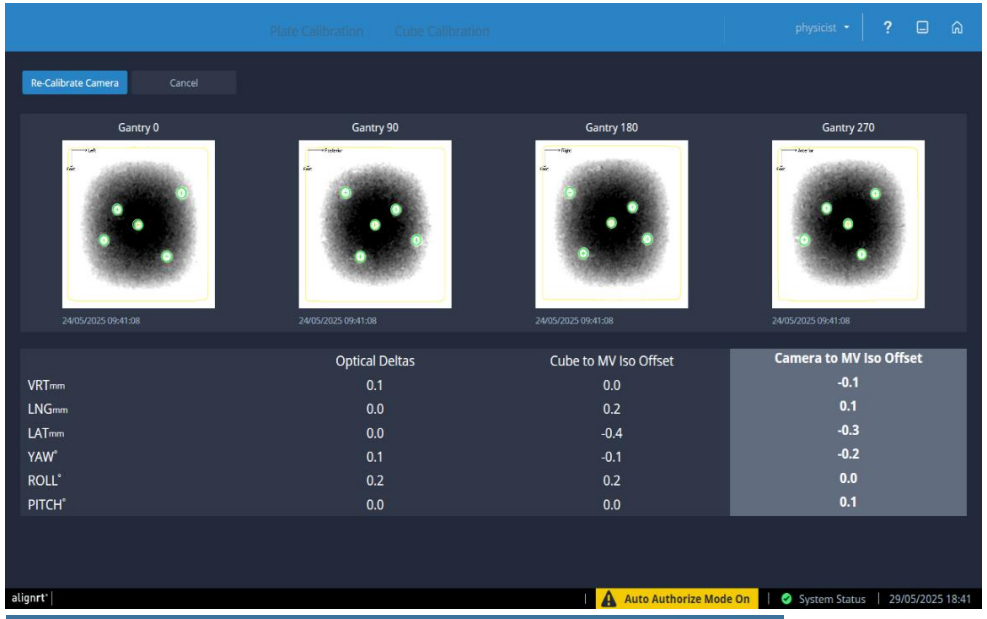
Tolerance

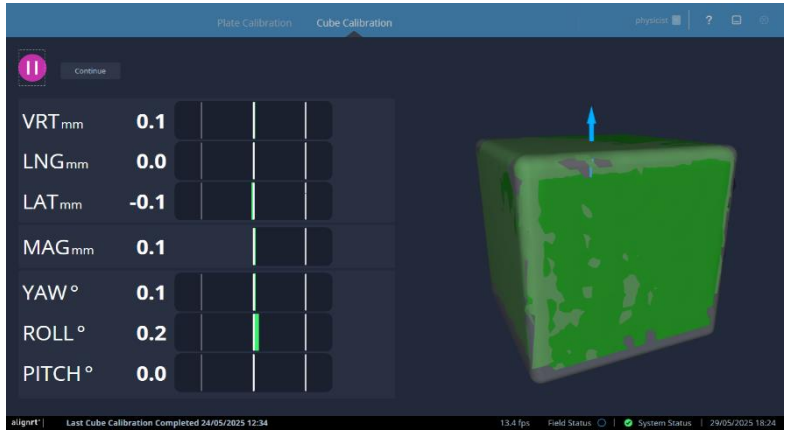
0.6 mm is warning level

1mm should be Re-calibration

Setup

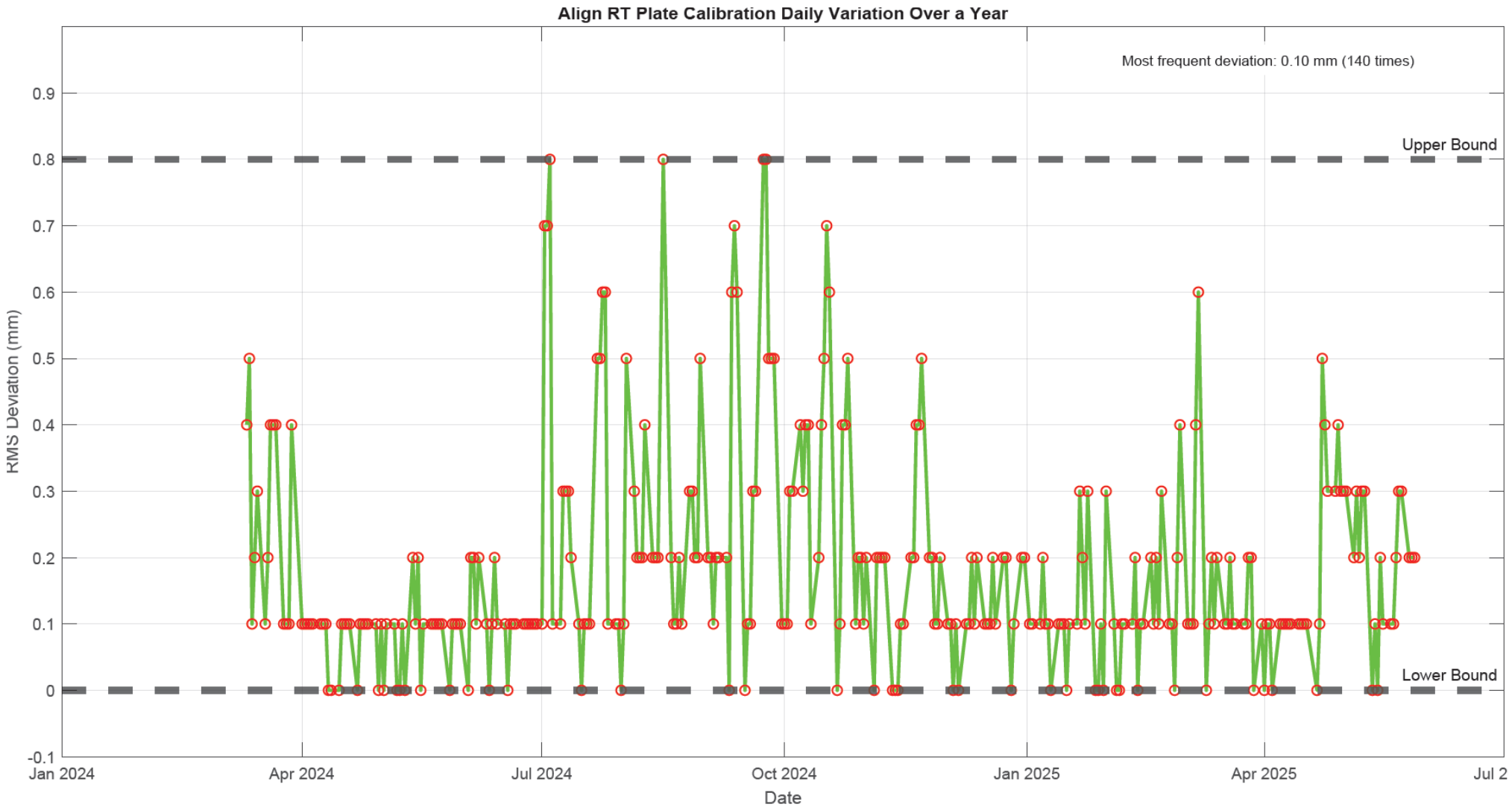
MV image acquistition



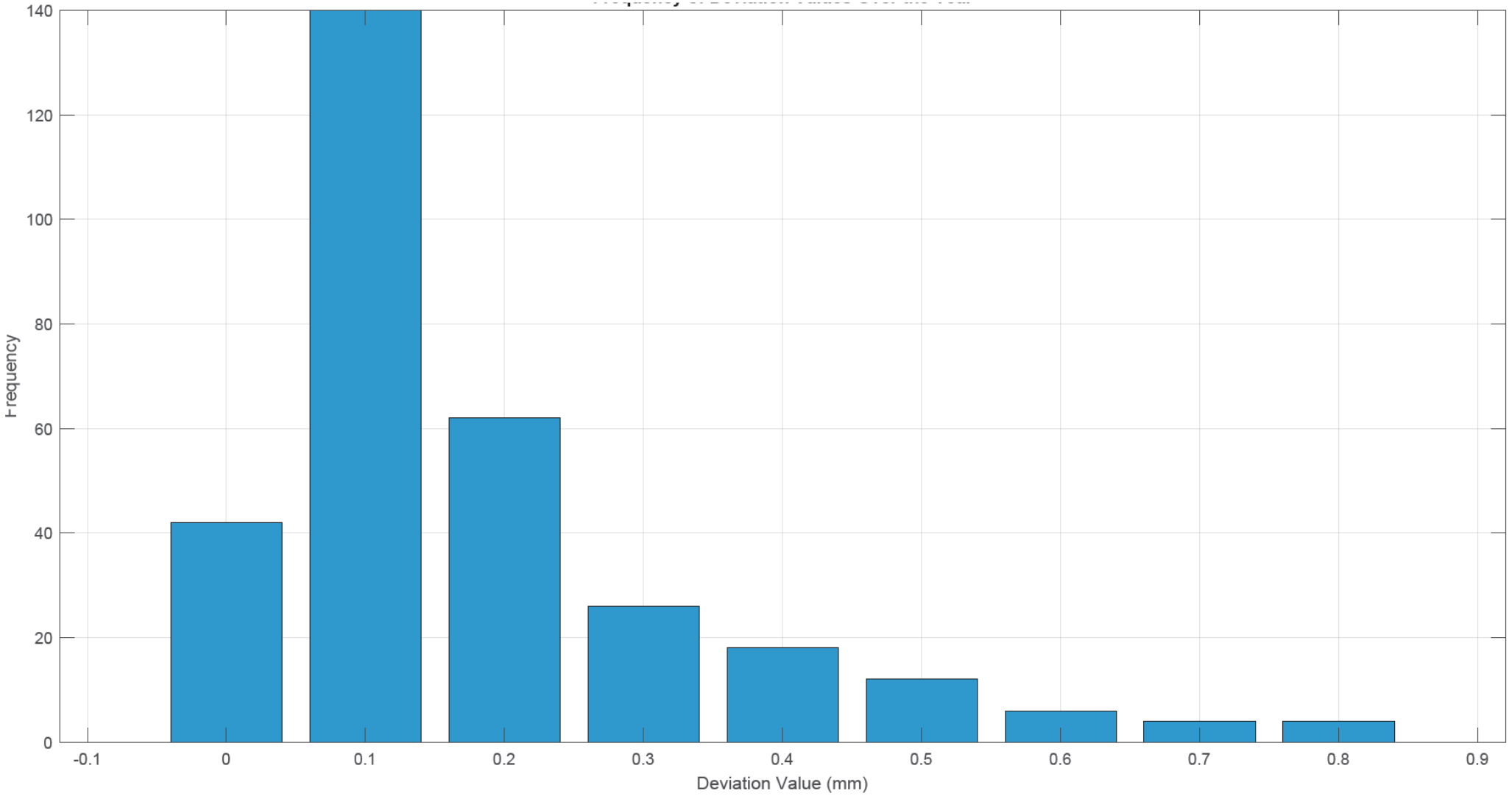


Calibration check

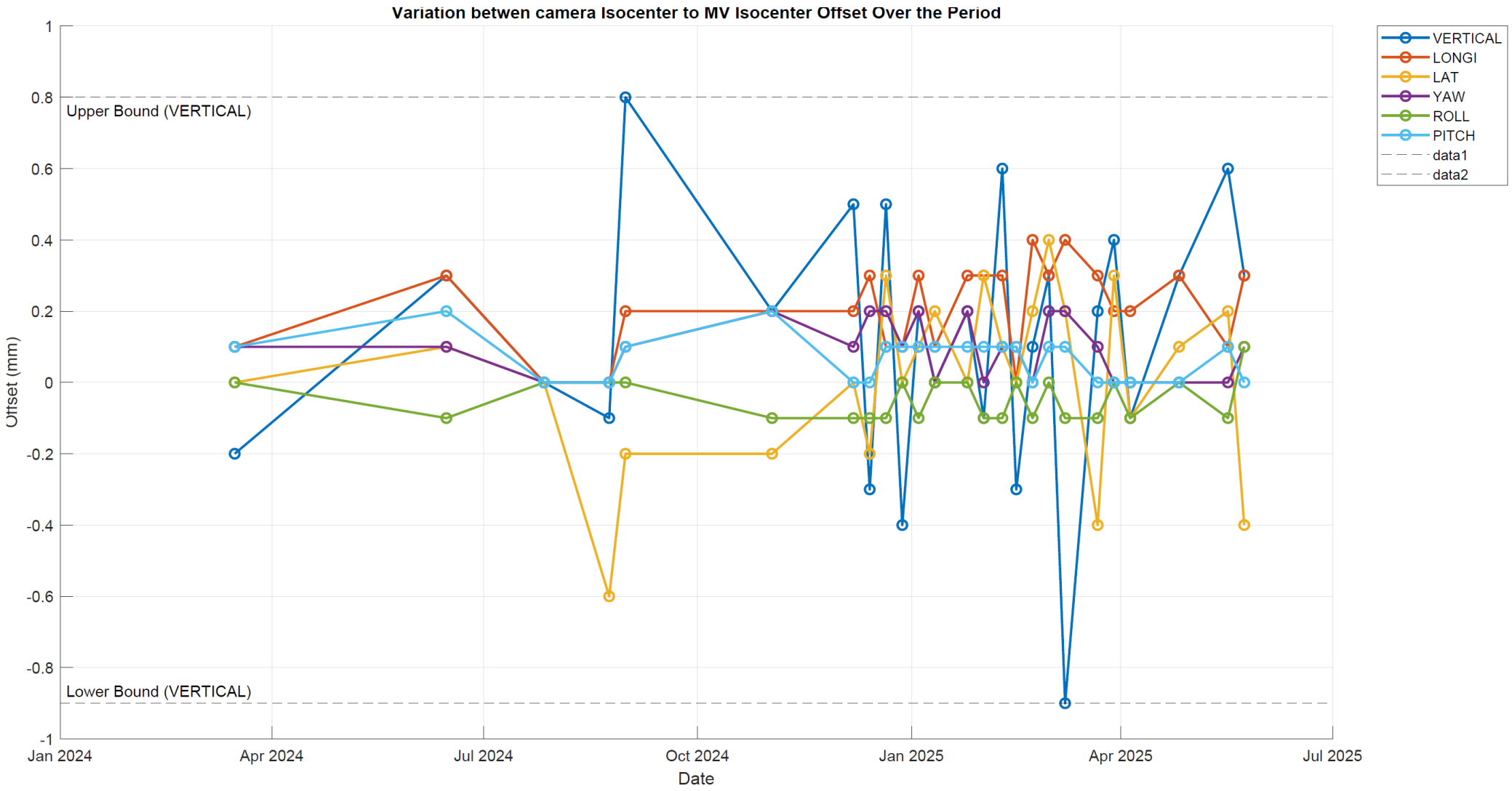
QA Results – Plate Calibration Check (Daily)



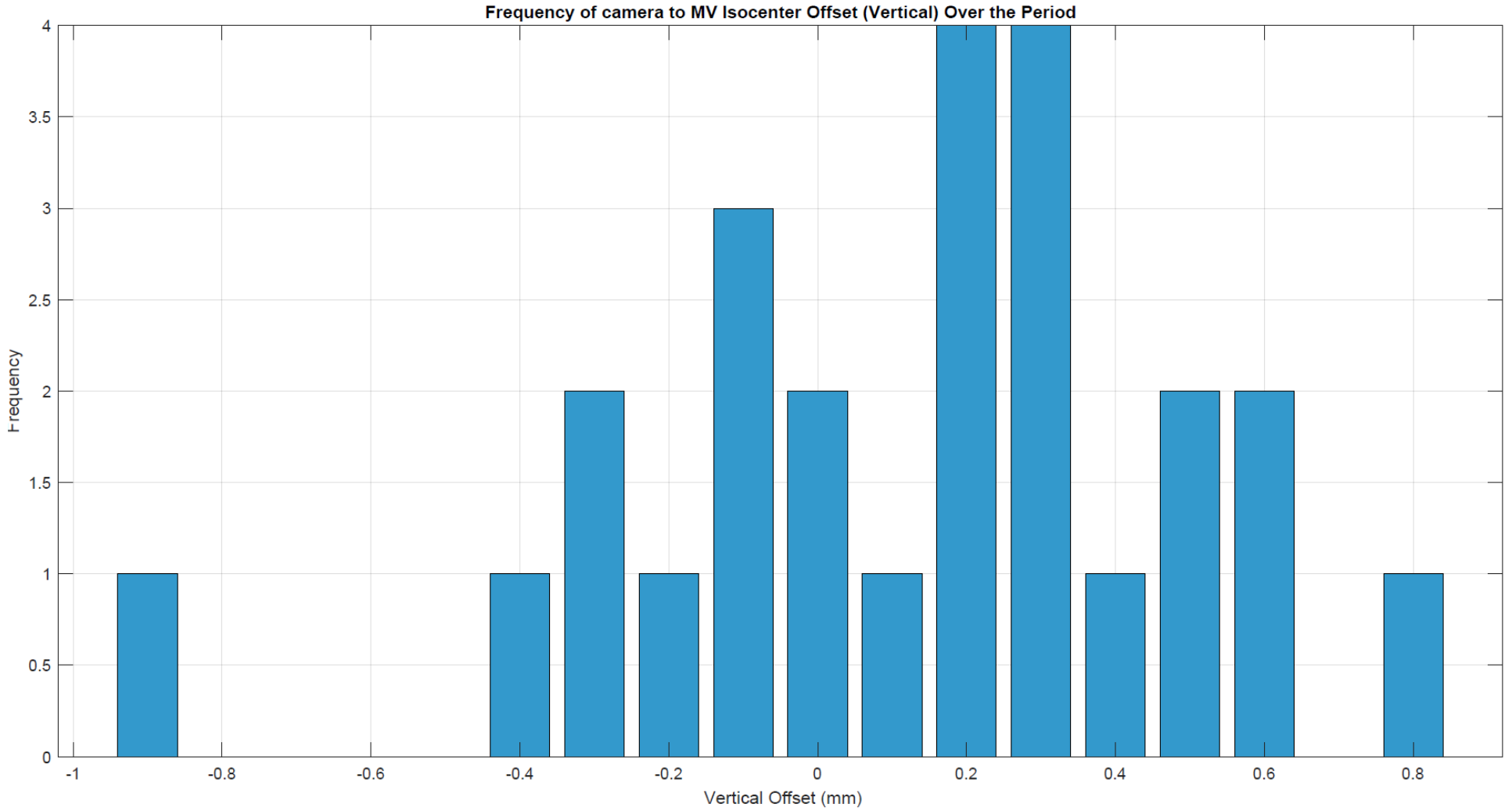
QA Results – Plate Calibration Check (Daily)…variation frequency



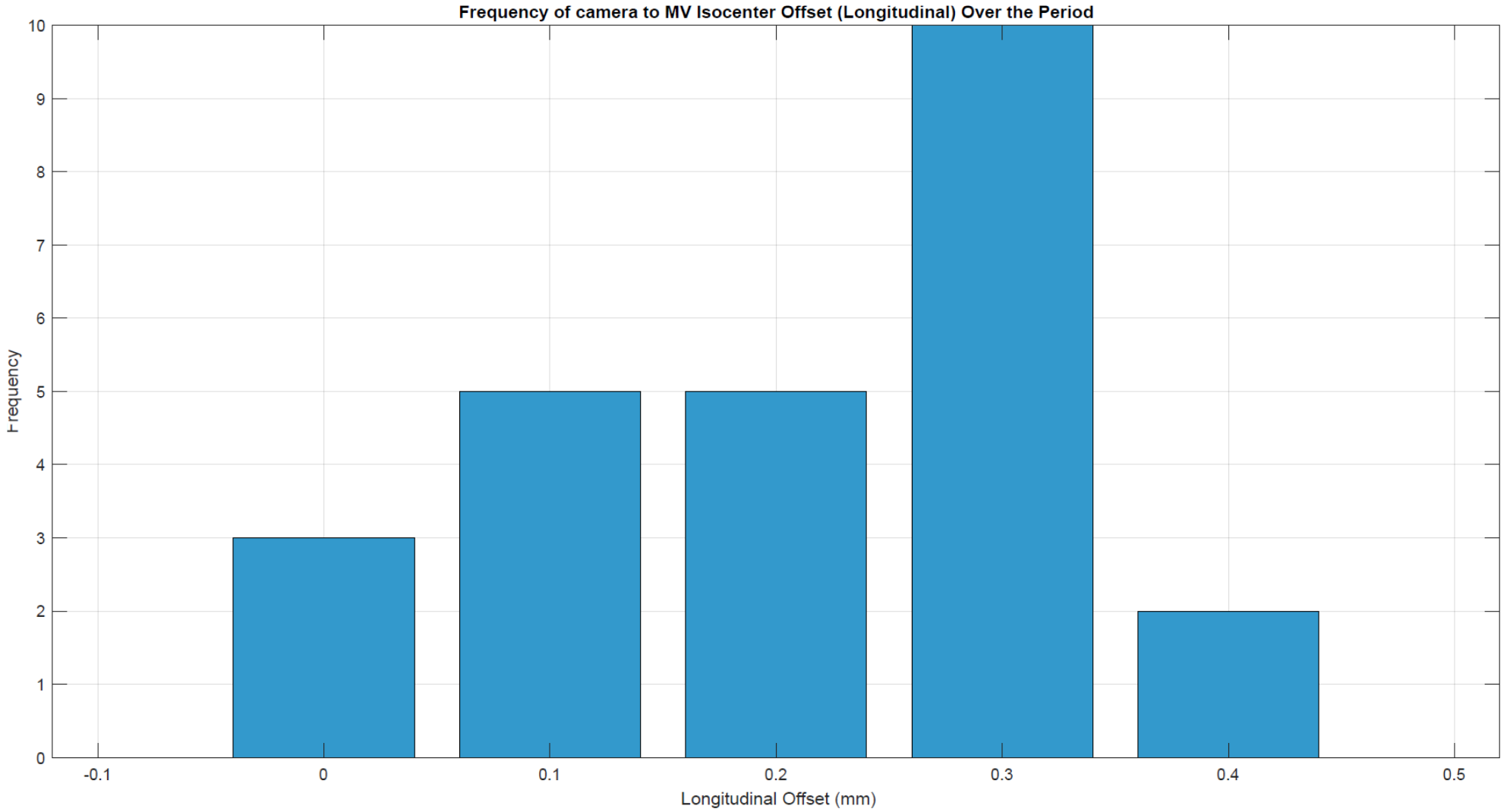
QA Results – Cube Calibration (Weekly)



QA Results – Cube Calibration (Weekly)



QA Results – Cube Calibration (Weekly)



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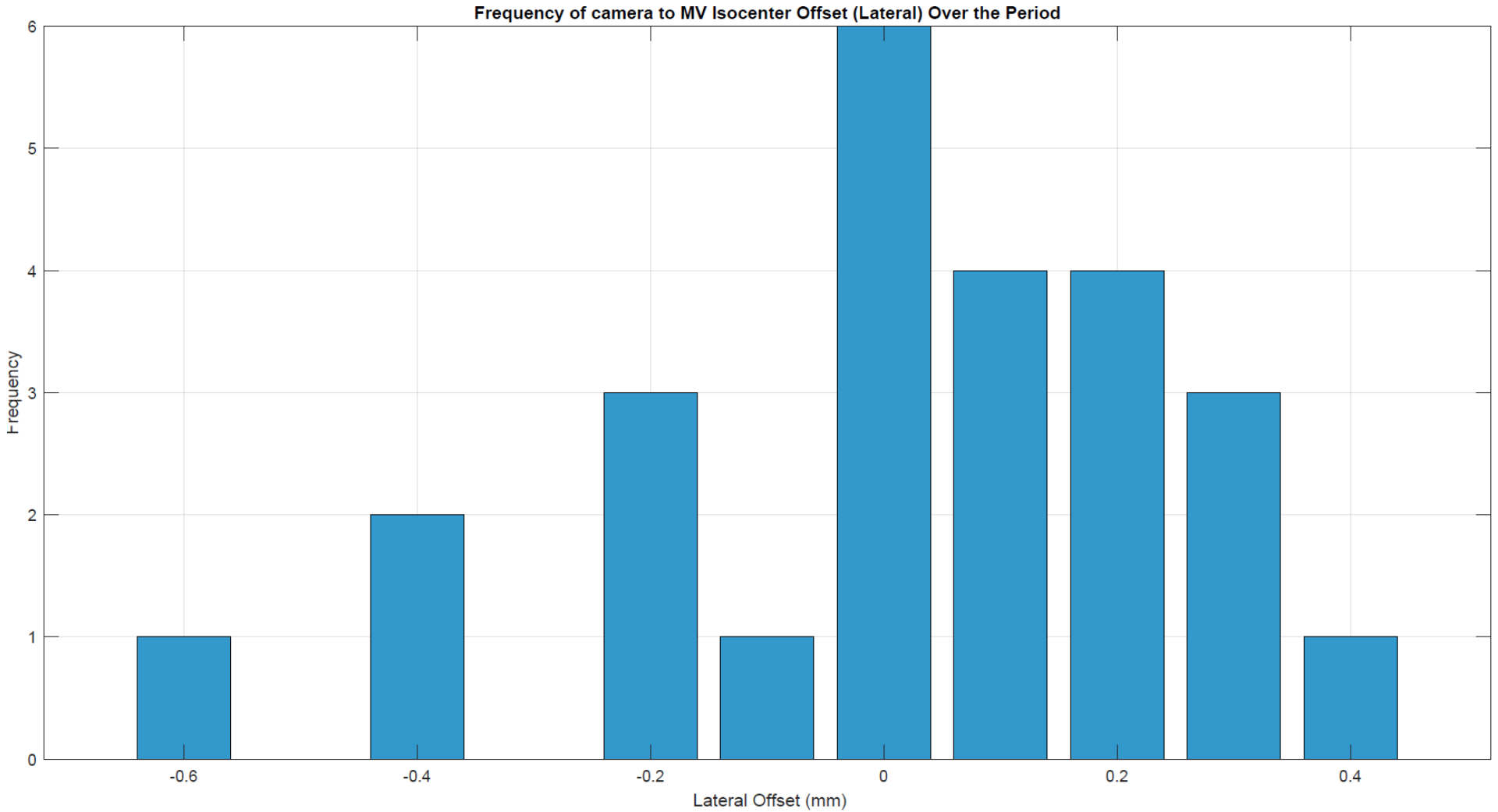
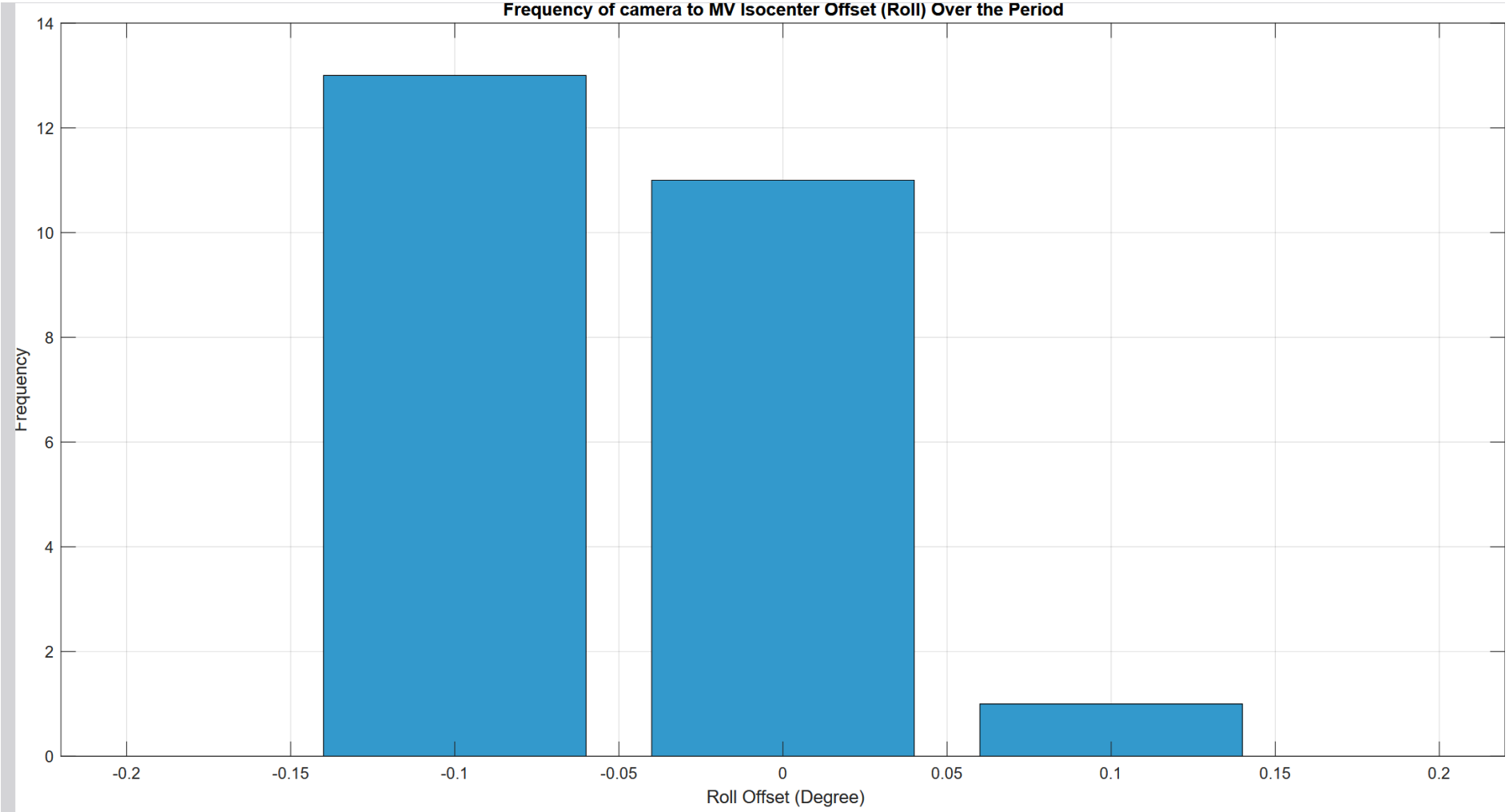


QA Results – Cube Calibration (Weekly)



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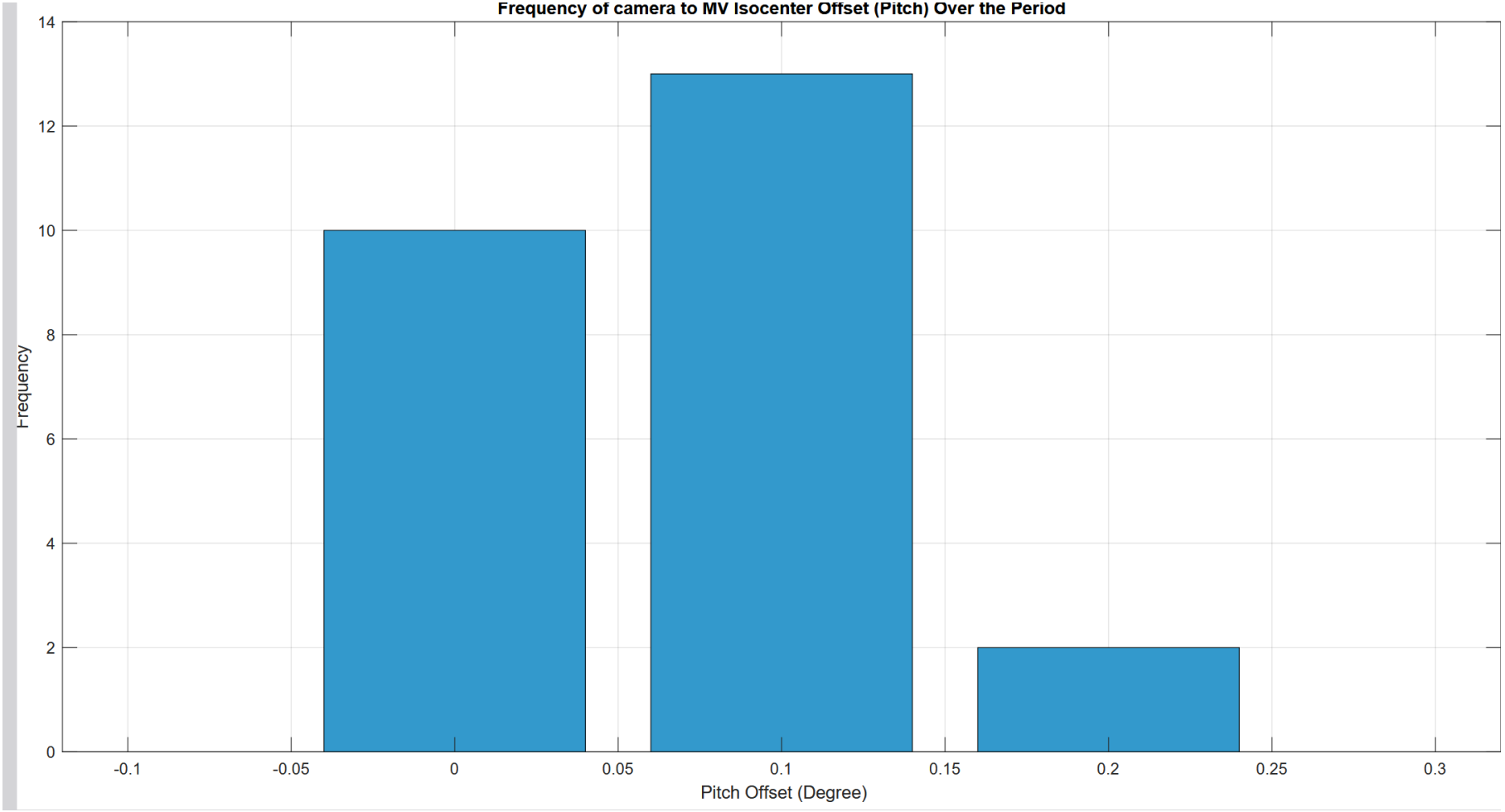
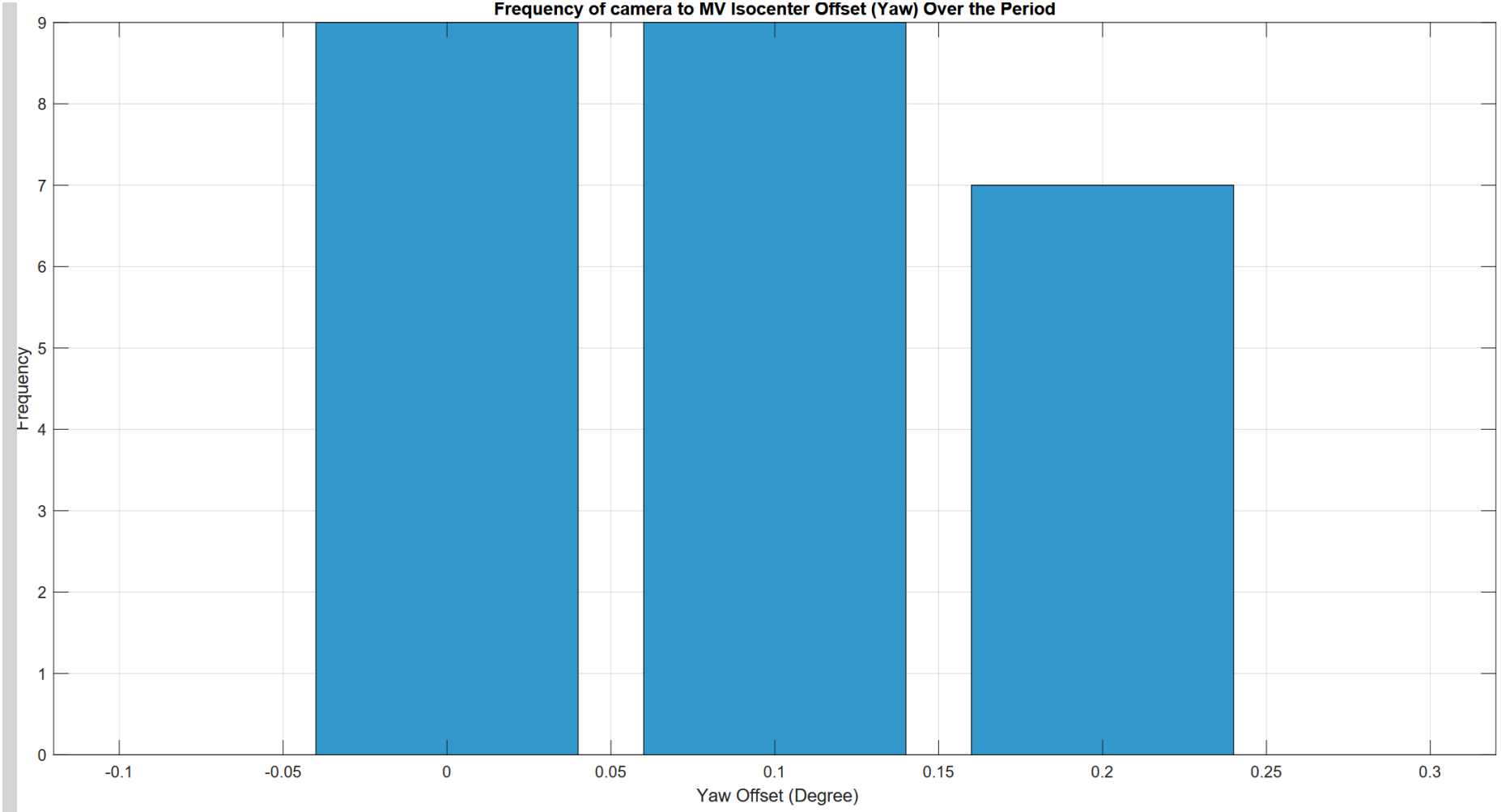
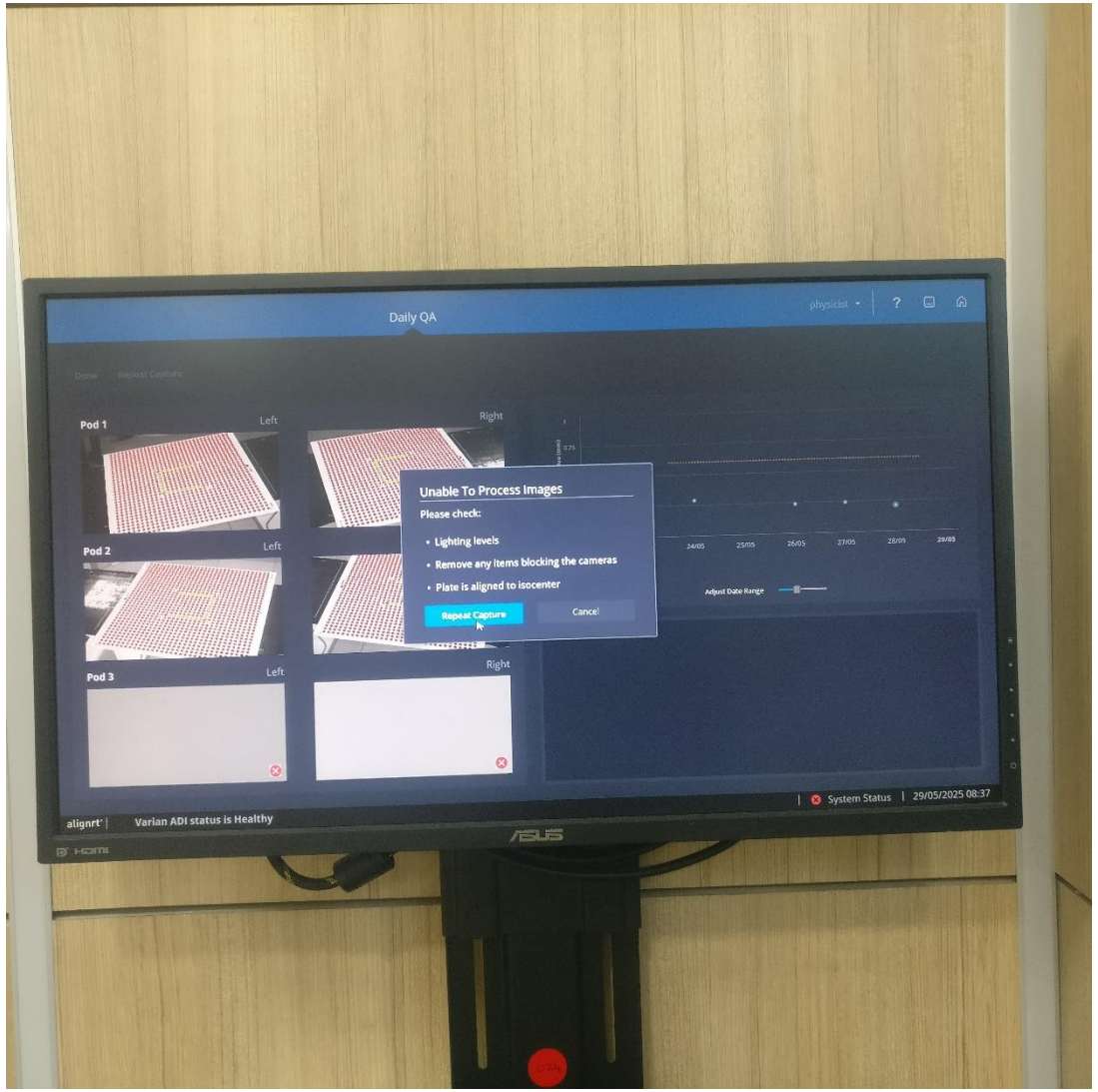


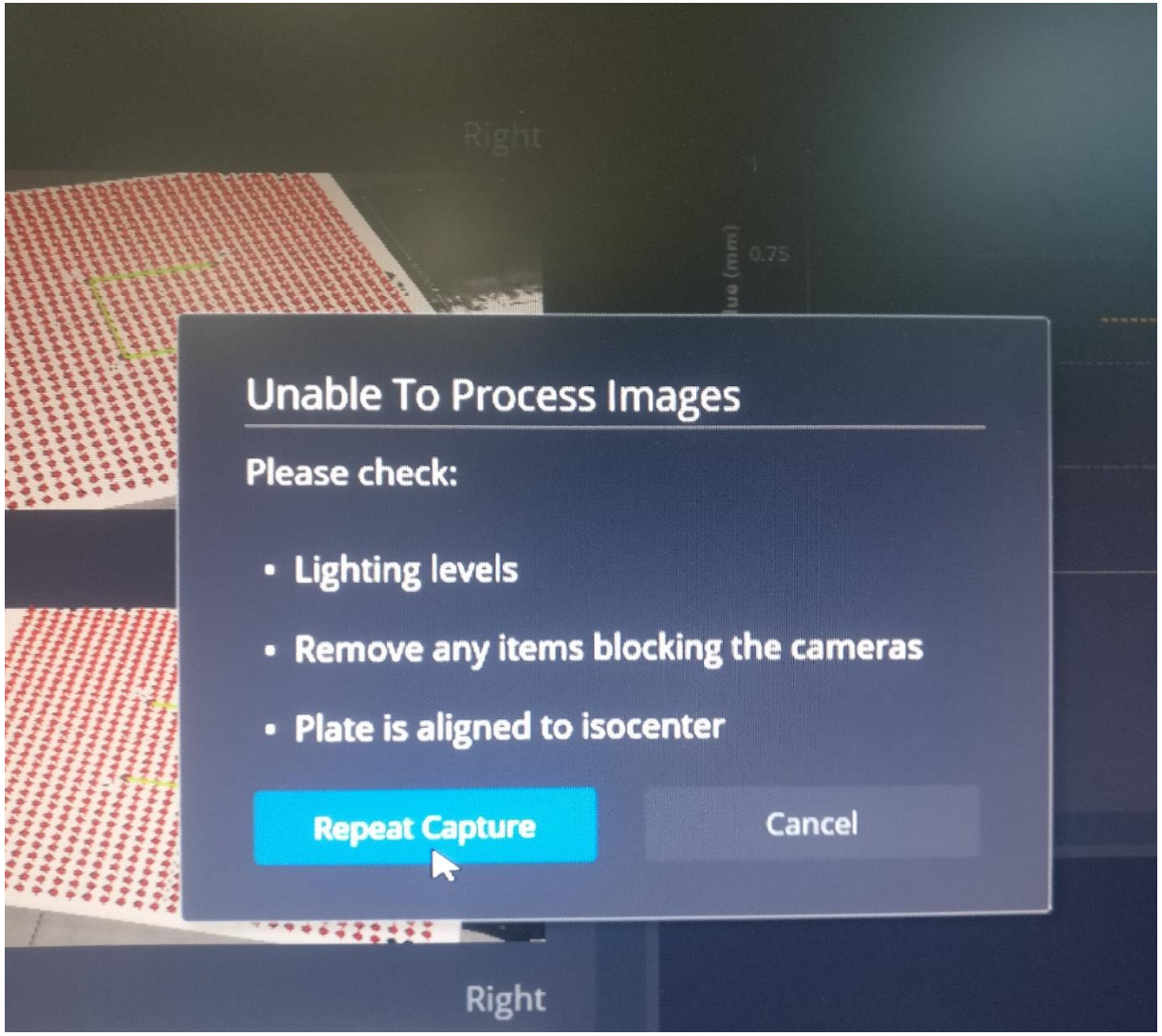
QA Results – Cube Calibration (Weekly)



Unexpected Challenges

Unexpected Challenges...variation in lighting levels





Summary

- Align RT is functioning as an **“independent observer”** in the room
- Routine SGRT **ensures safety** apart from **improvement of functionality** and **efficiency**
- Reliability of **stable camera** pods is reflected in the Daily QA check
- Having backup plan for any failure in **room lighting** would prevent unnecessary interruption in SGRT based treatment delivery
- Integration of SGRT with linac for DIBH during CBCT for IGRT is also an awaited solution

Thank You