Surface-Guided Radiation Therapy Complementing CBCT in Liver SBRT: A Pilot Study Using AlignRT

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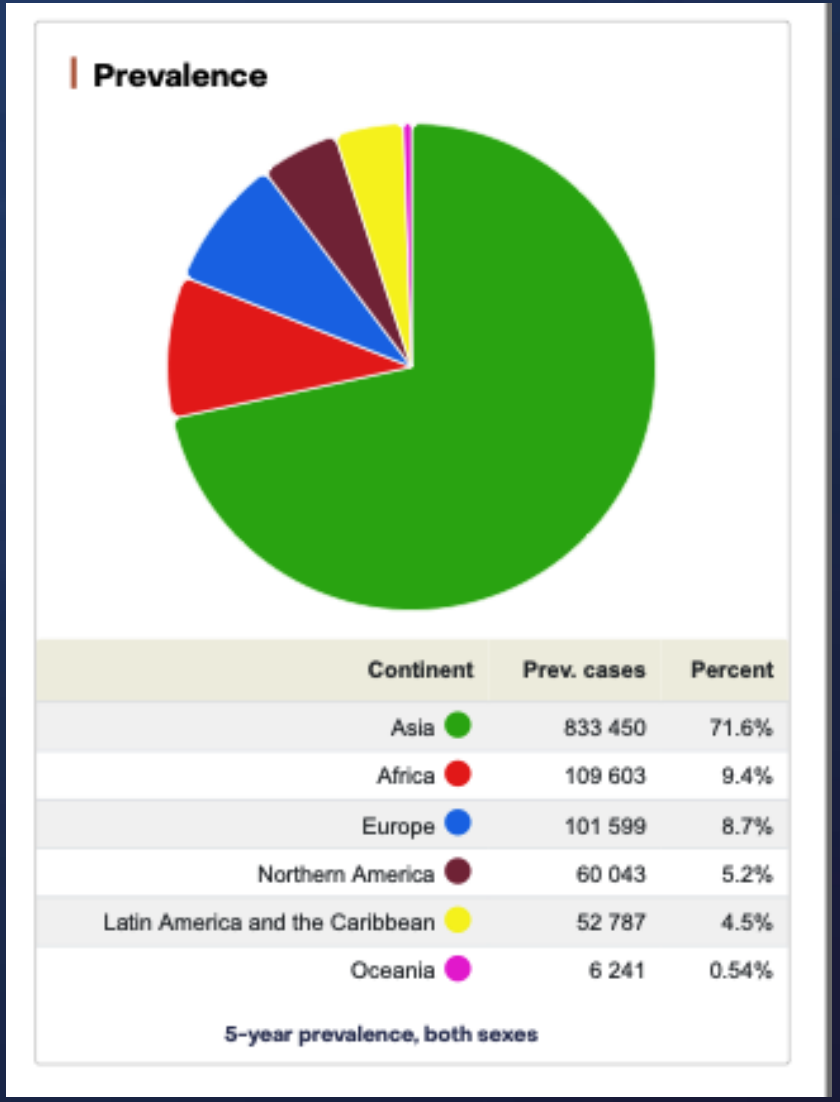
“As radiotherapy evolves, integration of imaging and surface guidance is redefining precision - transforming setup accuracy from a technical process into a patient-centred art.”

INTRODUCTION

- What is Hepatocellular Carcinoma (HCC)?
  - Primary liver cancer accounts for ~90% of all liver cancers.
  - 3rd leading cause of cancer-related deaths.
  - Strongly associated with chronic liver disease, hepatitis B/C, and cirrhosis (alcoholic, viral, or NAFLD-related).
  - Often diagnosed late, limiting curative options.
- Treatment Landscape:
  - Surgical resection or liver transplantation = ideal, but not always feasible.
  - Locoregional therapies (e.g., TACE, RFA) are used for early/intermediate stages.
  - Systemic therapies (targeted and immunotherapy).
  - Radiotherapy (SBRT) for inoperable or risky tumors.



- Image guidance in radiotherapy is crucial for high-precision treatment delivery.
- With IGRT, VMAT and IMRT, it is mandatory to have systems for online imaging.
- **Stereotactic Body Radiation Therapy (SBRT)** requires precise patient positioning so as to:
    - Deliver high doses of radiation with high precision
    - Minimise damage to surrounding healthy tissues
- **KV Cone Beam CT (CBCT):**
    - The gold standard for setup verification**.**
    - However, it uses ionising radiation.
- **Surface-Guided Radiation Therapy (SGRT):**
    - Optical imaging techniques**.**
    - Accurate patient positioning in 6 Degrees of Freedom (DOF).
    - Radiation-free, real-time patient positioning.
    - Reduces dependency on immobilization devices (e.g., thermoplastic masks).
    - Faster and more reliable patient setup for clinical moving sites.

Why Combine SGRT + CBCT in HCC?

- HCC patients often have breathing motion and liver displacement
- **CBCT** confirms internal alignment, **SGRT** ensures external stability throughout the session.
- **Objectives:**
  - To evaluate the potential of SGRT to complement CBCT for optimised patient setup accuracy in SBRT for HCC patients.
  - To assess the concordance between SGRT and CBCT in identifying setup shifts.
  - To determine the clinical feasibility of incorporating SGRT into routine liver SBRT workflows.

Study population

Patient Demographics:

- **Study Population:** 15
- **Age:** 30-73 years
- **Gender:** 14 Male, 1 Female
- **Study Setting:** Department of Radiotherapy and Clinical Oncology, PGIMER, Chandigarh, India.
- **Patient's geographical location:** Himachal Pradesh (2), Haryana (3), Punjab (7), Chandigarh (2), J&K (1)
- **Clinical characteristics:** Patients with HCC
- **Dose:** 30Gy/5# (7), 35Gy/5# (5), 40 Gy/5# (2), 50 Gy/5# (1)

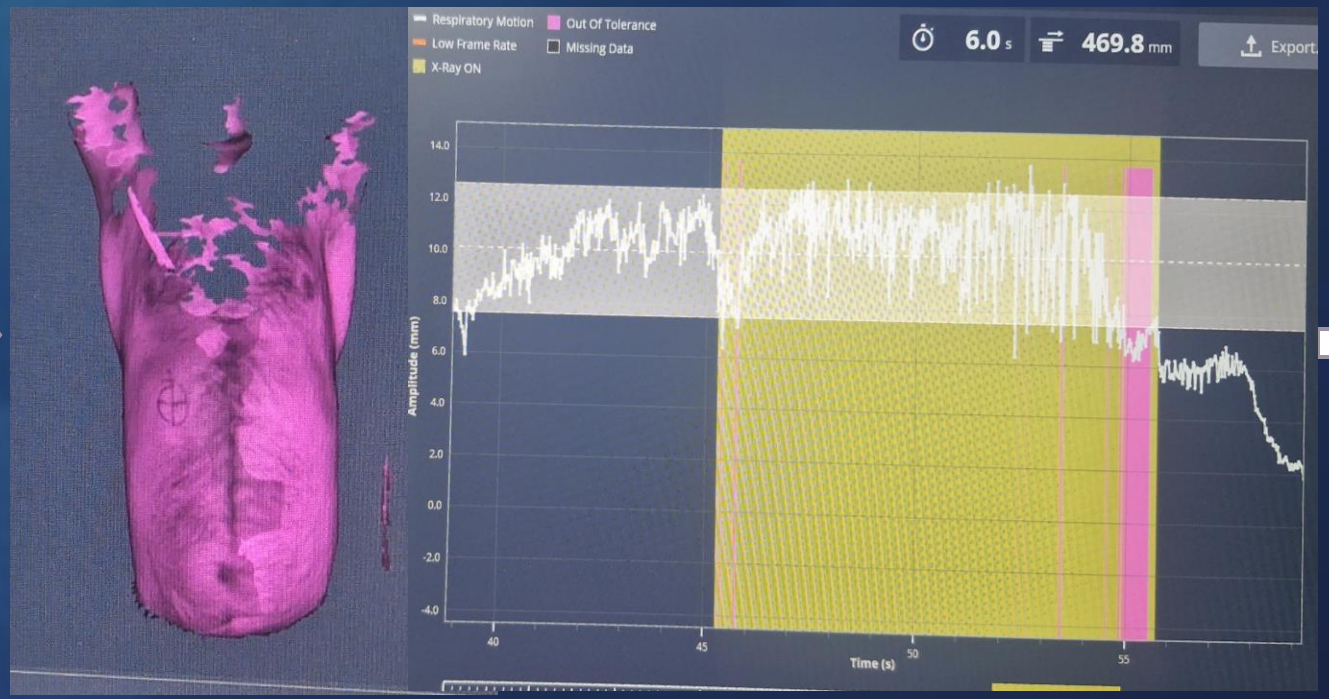
CT Simulation:

- **Purpose:** To take a reference image for comparison of positional setup errors.
- **Location:** Department of Radiotherapy and Clinical Oncology, PGIMER, Chandigarh
- **Equipment and material:** CT Simulator (SIEMENS Healthineers SOMATOM go. Sim) equipped with Sentinel System (Vision RT's OSMS, i.e. SimRT for SGRT)

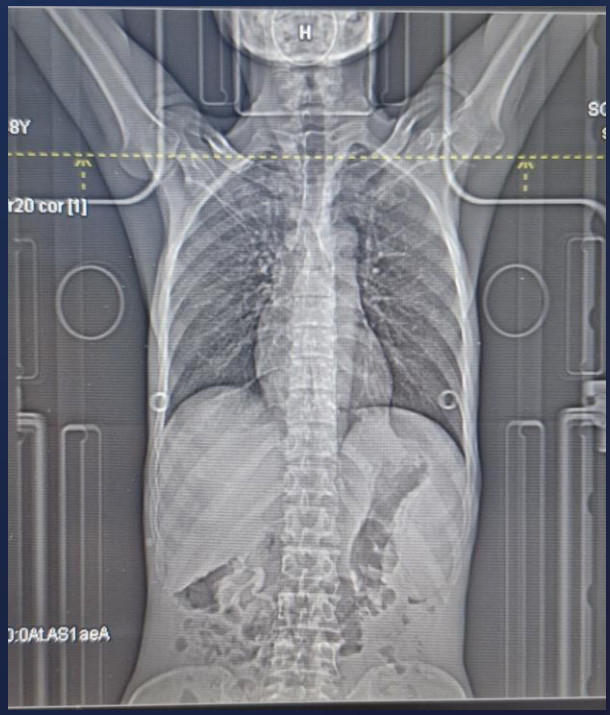
- **Procedure:**
  - The patient was positioned on the CT scan Table with internal laser isocenter and was scanned by the SimRT scanner.
  - A 3D image was produced, then saved for reference and a CT scan was performed (in breath hold) for treatment planning.

Laser Positioning

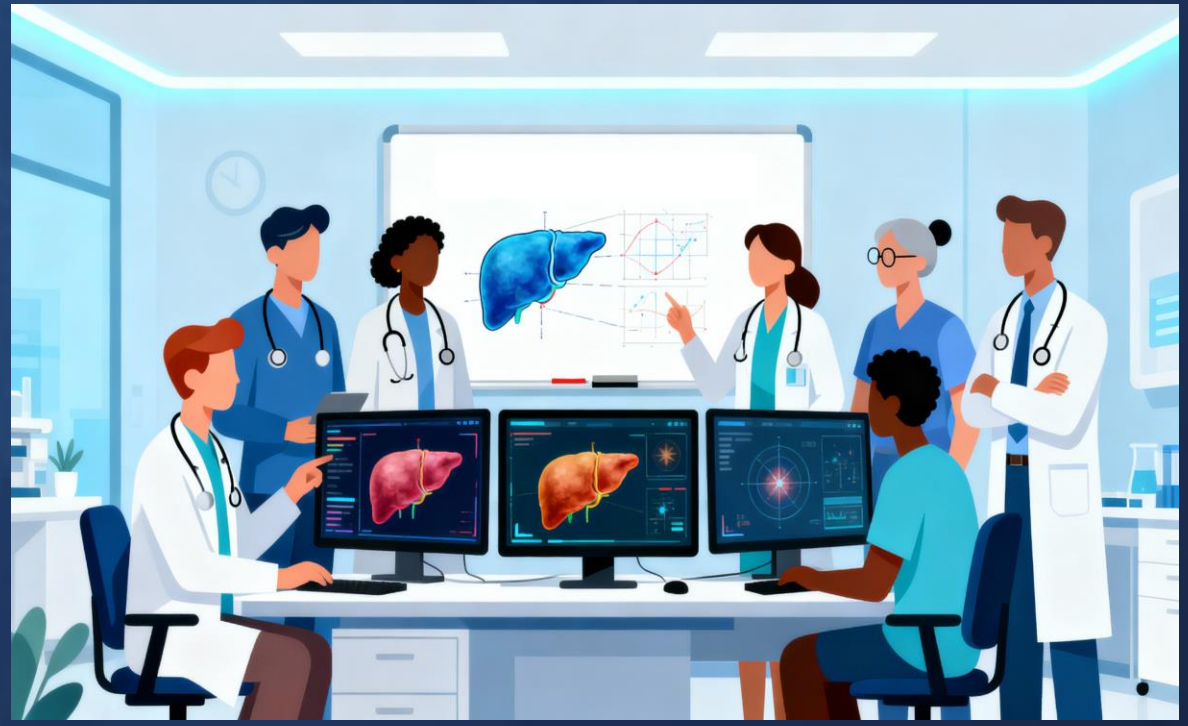
Surface Imaging with SimRT



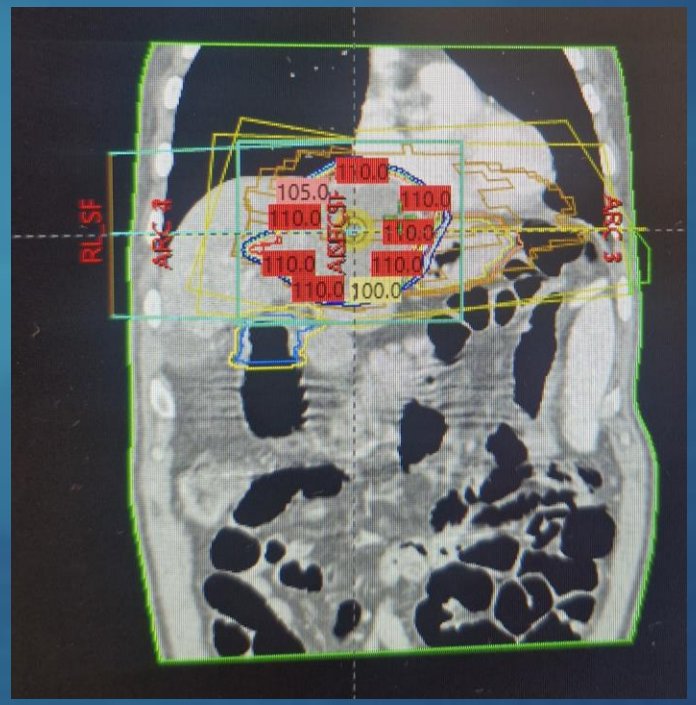
CT scan imaging

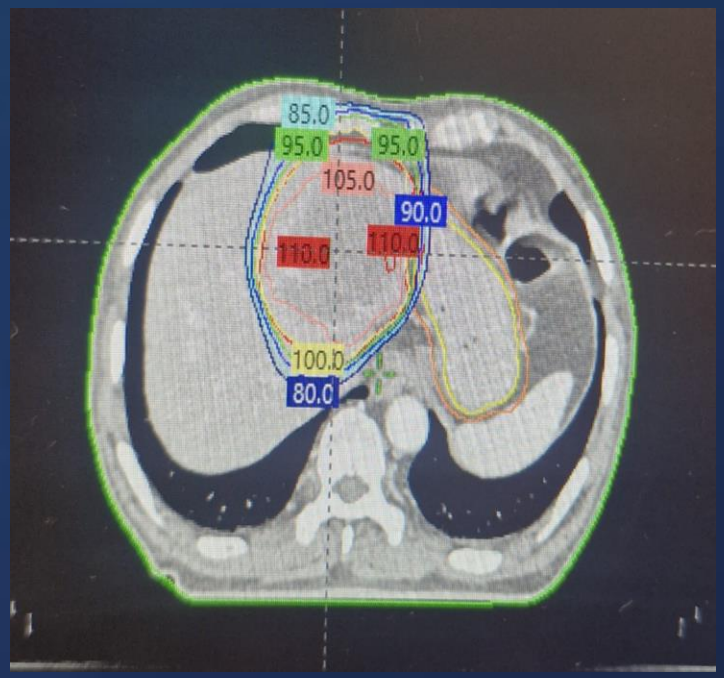


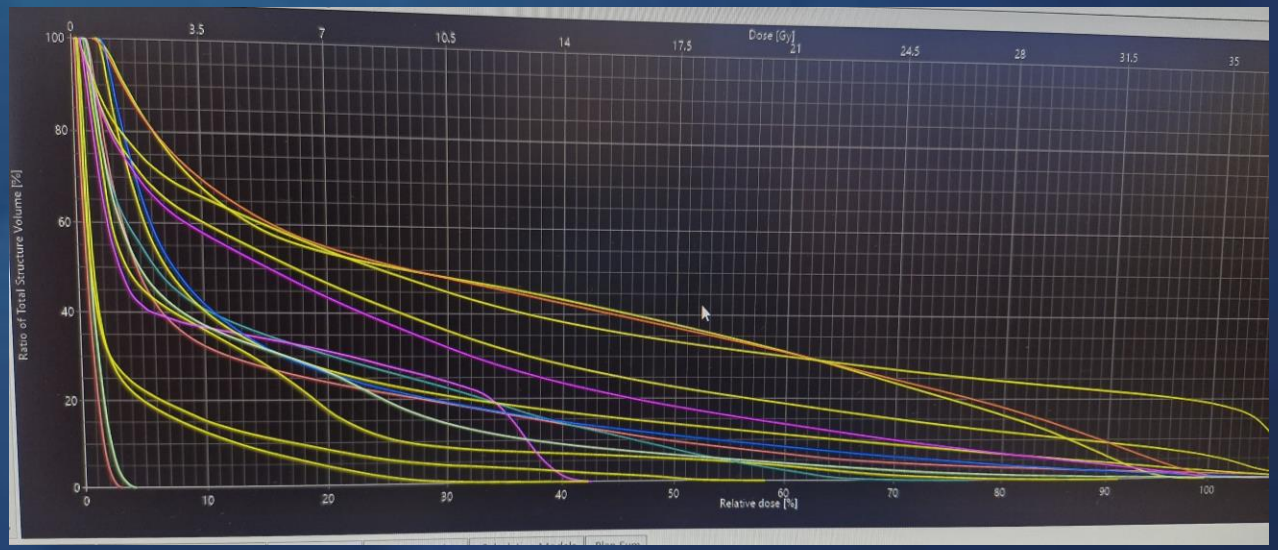
Treatment Planning:



- **Location:** Department of Radiotherapy and Clinical Oncology, PGIMER, Chandigarh
- **Equipment and material:** TPS system
- Accurate breath hold contours were made by Oncologists, and the dose to be delivered for radiation therapy was defined.
- The technique to deliver the dose was designed by Medical physicist according to tumor area and dose specifications.
- Treatment plan and body contour were exported to Treatment Delivery Unit (Varian TrueBeam Linear accelerator equipped with AlignRT system- SGRT system)







Treatment Planning of HCC: Upper 3 images represent the region of interest for radiation, lower left image shows DVH and the lower right image shows the Arc direction at different angles to deliver radiation.

Treatment Delivery:

- **Location:** Department of Radiotherapy and Oncology, PGIMER, Chandigarh
- **Equipment and material:** Varian TrueBeam Linear accelerator equipped with AlignRT System (VisionRT's three-camera OSMS for SGRT)

Procedure:

Patient positioned on the treatment table using SimRT's reference surface.

Live SGRT 3D image (from AlignRT) compared with the reference surface image.

Positional variations were corrected

CBCT verification in breath-hold position.

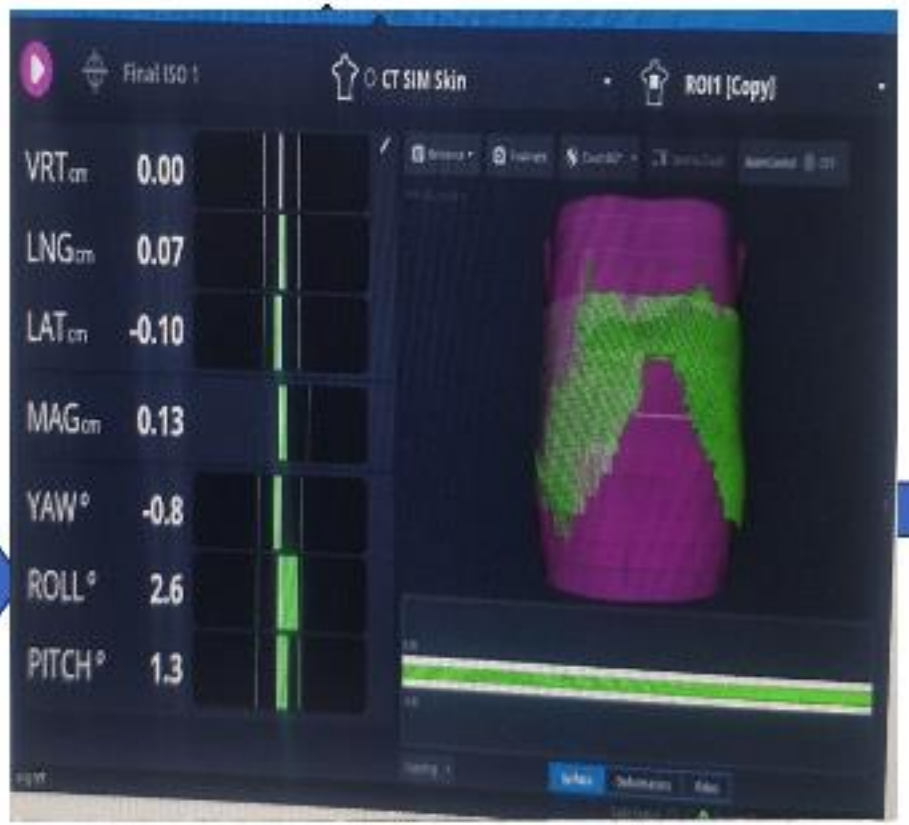
Positional variations were corrected

Treatment is delivered (< ± 5 mm/ 5° tolerance limit). Otherwise, the position set up is revised again.

Same procedure was followed for every fraction of radiation for one patient and then for every other patient

Laser positioning

Surface imaging with the AlignRT system with positional shifts



CBCT Scanning with positional shifts

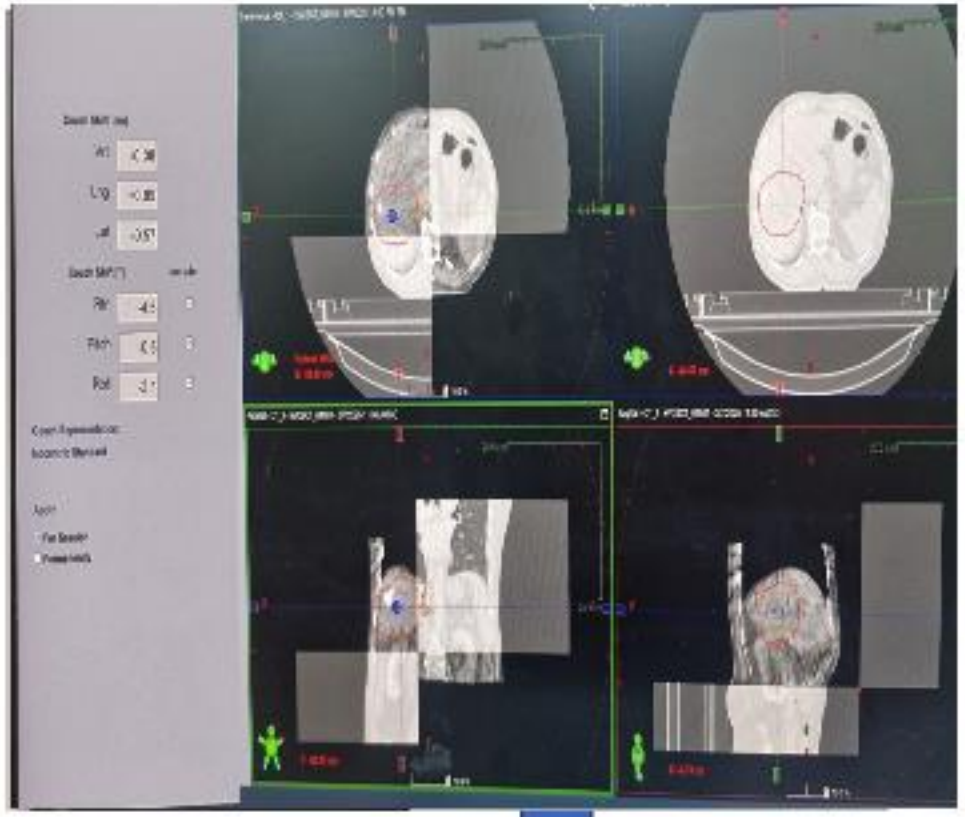


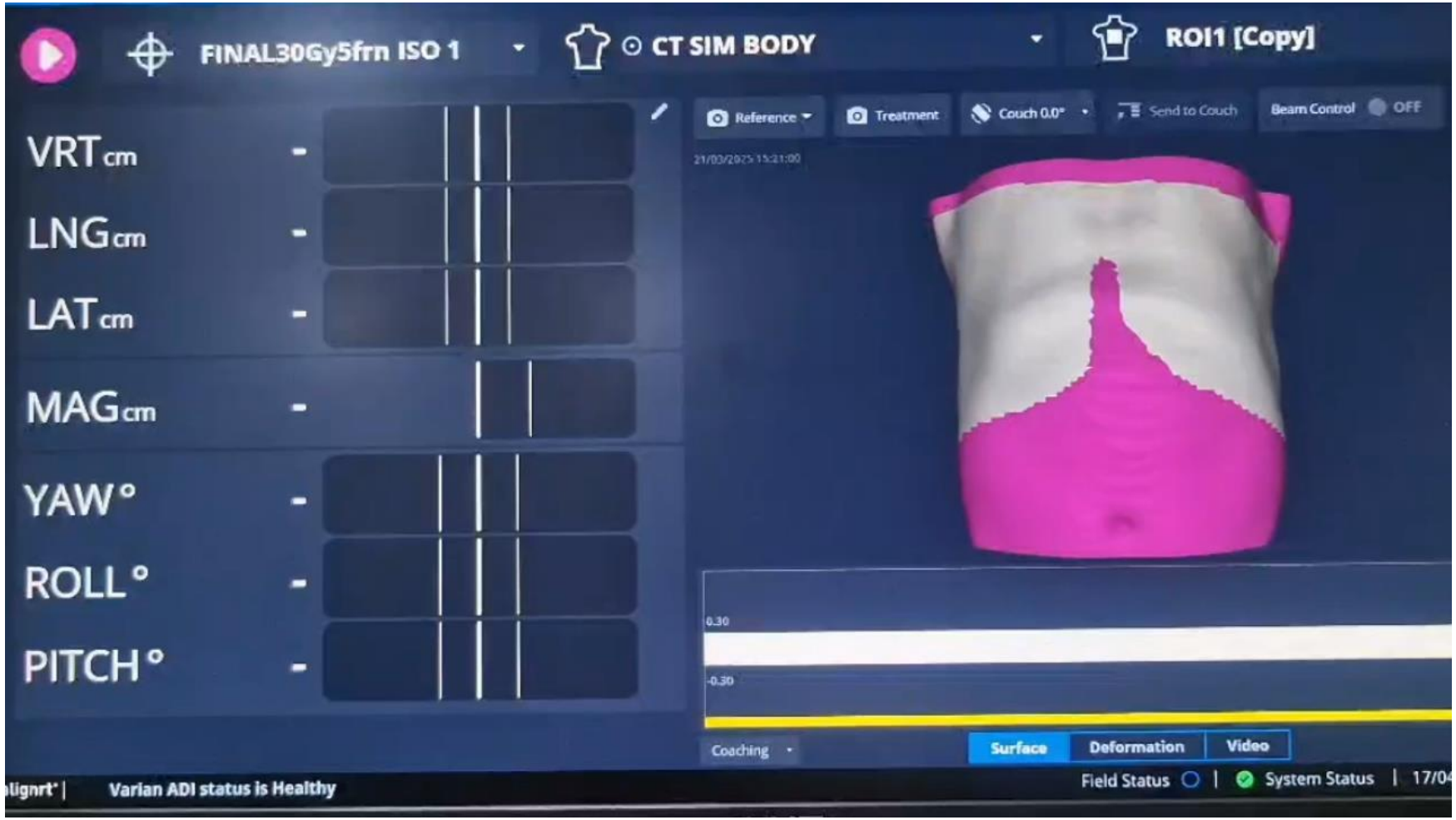
Table corrections were applied and Treatment is delivered

Acquired displacement and Rotation errors were recorded from both surface scanning and CBCT for comparison in our study.

Summary

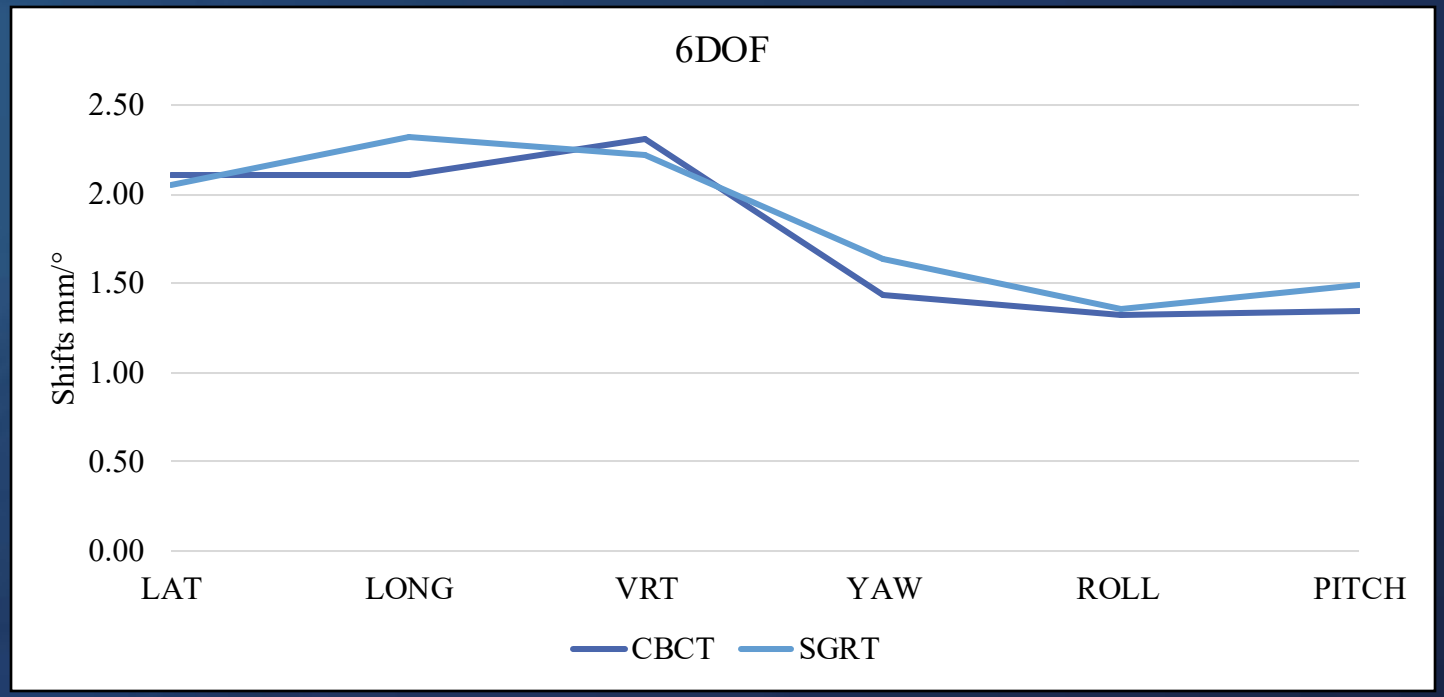
CT Simulation → Treatment Planning → Treatment Verification → Translational, rotational shifts noted, applied and treatment delivered → Paired **t-tests** and **F tests** performed to compare shifts between CBCT and SGRT across 6 degrees of freedom (DOF).

Video:



Results

The results from the complete data of 15 patients (77 fractions):



Axis	CBCT Mean ± SD	SGRT Mean ± SD	P value of t-test	P value of F test
Lateral	2.11 ± 1.08 mm	2.05 ± 1.26 mm	0.76	0.42
Longitudinal	2.11 ± 1.29 mm	2.32 ± 1.19 mm	0.28	0.27
Vertical	2.31 ± 1.10 mm	2.21 ± 1.08 mm	0.64	0.21
Yaw	1.44 ± 0.96°	1.64 ± 1.15°	0.36	0.14
Roll	1.32 ± 0.83°	1.36 ± 0.78°	0.79	0.04
Pitch	1.35 ± 0.83°	1.50 ± 1.17°	0.37	0.16

Conclusion

SGRT shows alignment similar to CBCT with minor differences, indicating its reliability for external positioning.

- **SGRT benefits:**
  - Supports **tattoo-less workflows**, enhancing patient experience.
  - **Reduces imaging frequency,** lowering patient exposure to ionizing radiation.

CBCT remains critical for internal organ verification, ensuring precise dose delivery.

- **Future Directions:**
  - Conduct **larger studies** to confirm these pilot findings.
  - Investigate further how **SGRT integration** can optimize treatment planning and delivery for other tumors.

Acknowledgement

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Fighting Cancer is a team effort