SURFACE GUIDED RADIOTHERAPY

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DEFINITION

Surface-guided radiation therapy (SGRT) uses 3D imaging to track a patient's position and movement during treatment by an noninvasive and nonionizing technologies, ensuring accurate radiation delivery and improving safety and precision

SGRT typically uses visible structured light, stereo-vision systems, time-of-flight systems, or laser scanners to image the surface of a patient with high temporal and spatial resolution without additional radiation dose

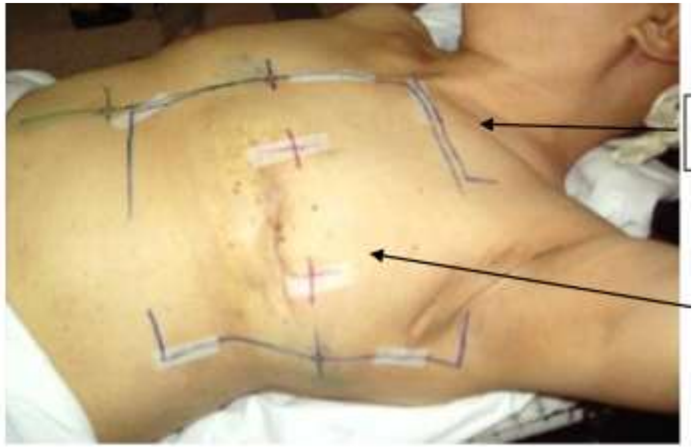


image-guided radiation therapy (IGRT) uses two- (2D) or three-dimensional (3D) images for setup verifications.

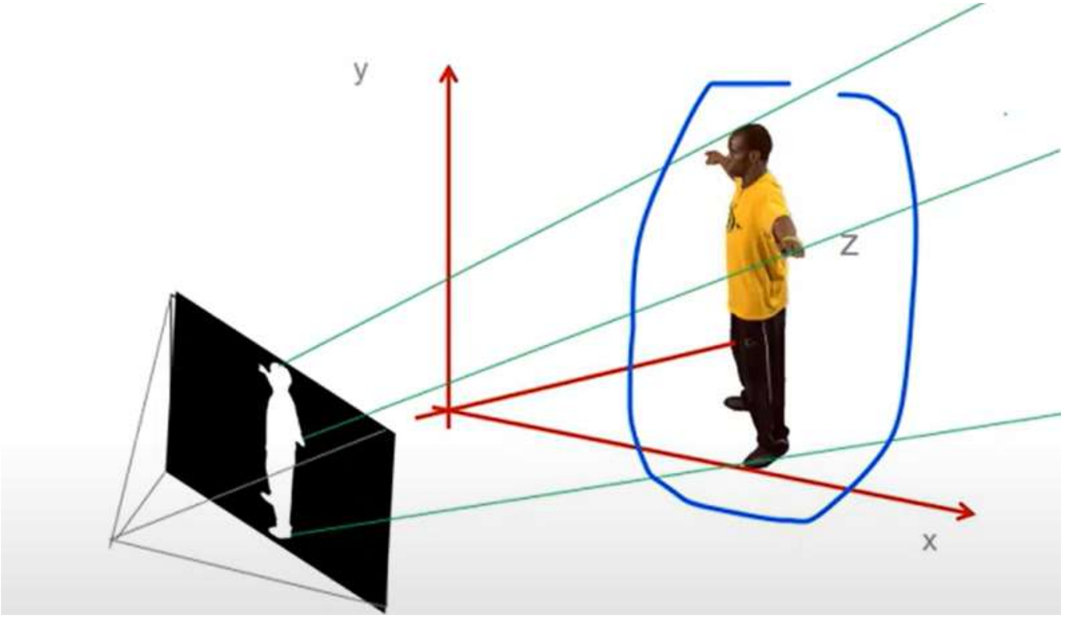
Limitation : a) ionizing imaging, giving an additional dose to the patients
b)difficult to determine the skin surface positions
c) picture of the patient at a particular chosen moment (before or after the treatment beam) but no continuous monitoring is possible

How it works :

Triangulation technique

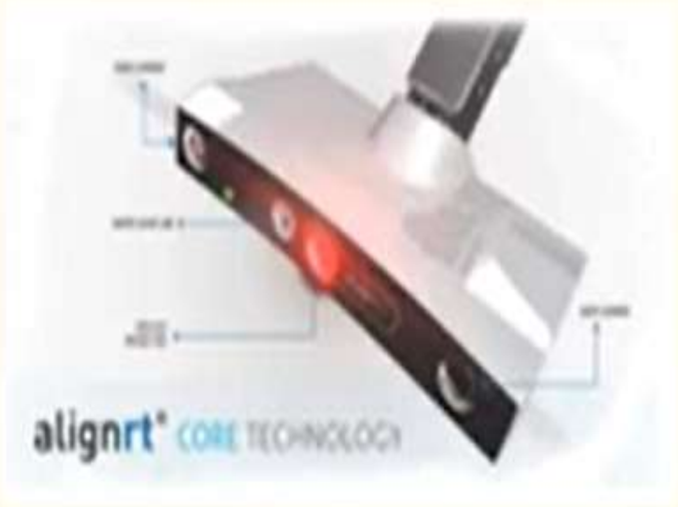
3D reconstruction from multiple images, allows to reconstruct the 3D geometry of a scene from its 2D projections.

Triangulation in 3D reconstruction is the process of determining the 3D location of a point in space using the projections of that point onto two or more images.



C-RAD

visionrt



varian

IDENTIFY

AAPM task group report 302: Surface-guided radiotherapy

Hania A. Al-Hallaq[1] | Laura Cerviño[2] | Alonso N. Gutierrez[3] |

System (Vendor)	Optical technology	Camera size (W × H × D); Weight	Field-of-view* (Lat × Long × Vert)	Camera resolution	Frame rate	Positioning accuracy#	Registration algorithm
AlignRT (Vision RT)	Stereovision using a speckle pattern	430 × 66 × 186 mm; 4.5 kg	650 × 1000 × 350 mm^3	2048 × 2048 px (4MP)	4-24 fps	<1.0 mm <1.0°	Rigid
Catalyst (C-RAD)	Structured light imaging	620 × 390 × 280 mm; 16 kg	1100 × 1400 × 2400 mm^3	640 × 480 px (0.3 MP)	8-24 fps	<1.0 mm <1.0°	Deformable[27]
IDENTIFY (Varian)	Stereovision using a speckle pattern	500 × 80 × 182 mm; 3.3 kg	500 × 500 × 400 mm^3	1280 × 1024 px (1.3 MP)	10 fps	<1.0 mm <1.0°	Rigid

System (Vendor)	Treatment unit# hardware	CT Simulator system (vendor)	Patient identification	Patient biofeedback	Patient positioning Corrections
AlignRT (Vision RT)	1 to 3 cameras units (~90° apart)	GateCT (Vision RT)	Infrared facial recognition	Visual (Real-time coach)	6D
Catalyst (C-RAD)	1 to 3 cameras units (120° apart)	Sentinel* 4DCT (C-RAD)	Facial recognition	Audio & visual (Goggles)	6D
IDENTIFY (Varian)	3 cameras units (~90° apart)	IDENTIFY CT (Varian)	Palm reader	Visual coaching module	6D

three ceiling- mounted camera pods.

Pods 1 and 2 are located approximately 30 cm offset from the left and right lateral positions, respectively

Pod 3 is located at the foot of the treatment couch

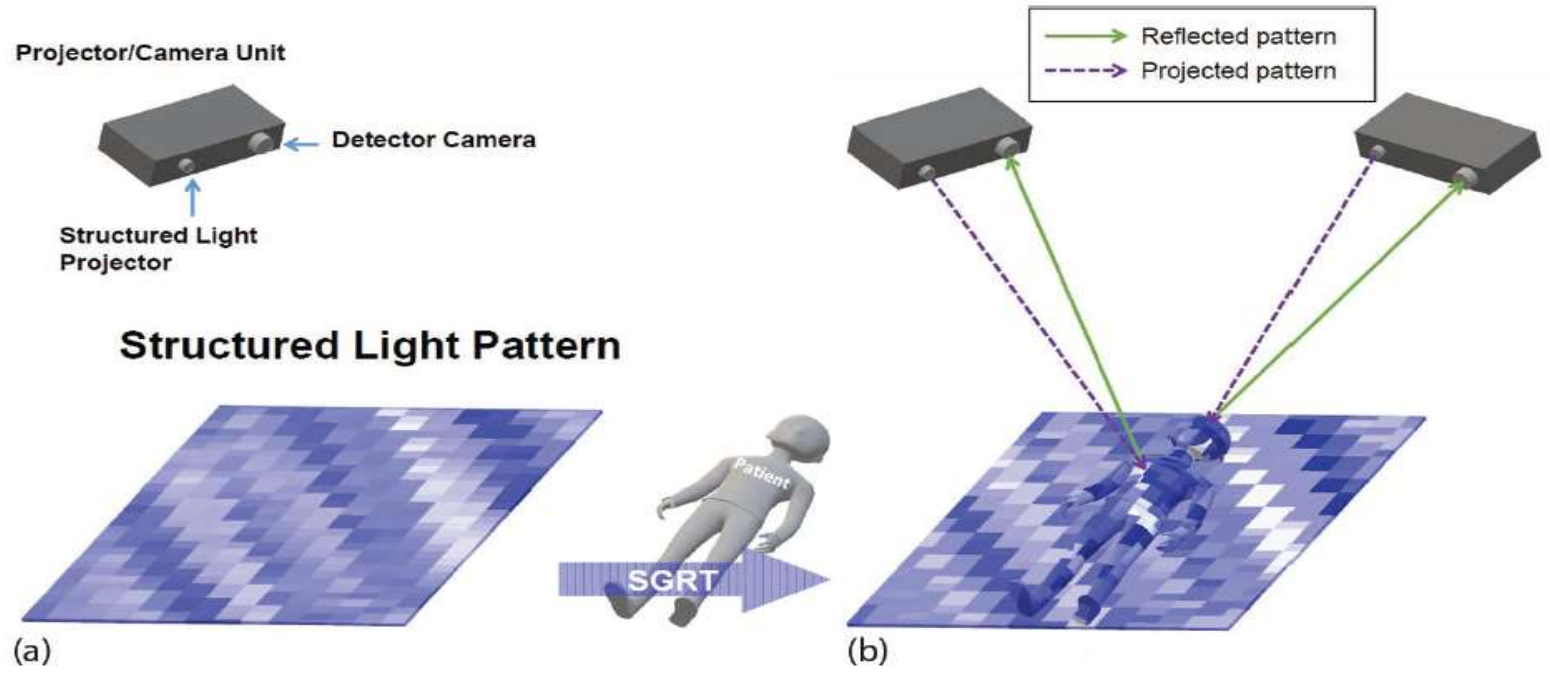
HOW TO ACHIEVE TRIANGULATION IN SGRT SYSTEM

Stereophotogrametry

Stereo meaning solid/ 3D
photo meaning “light,”
gram meaning letters or drawing,
metry meaning “measure

visible red light with a pseudo-random speckle pattern is projected from each camera pod onto the patient.

(2D) information from each of the camera sensors can be converted into a series of 3D coordinates via “triangulation” and visualized as a real-time surface rendering of the patient

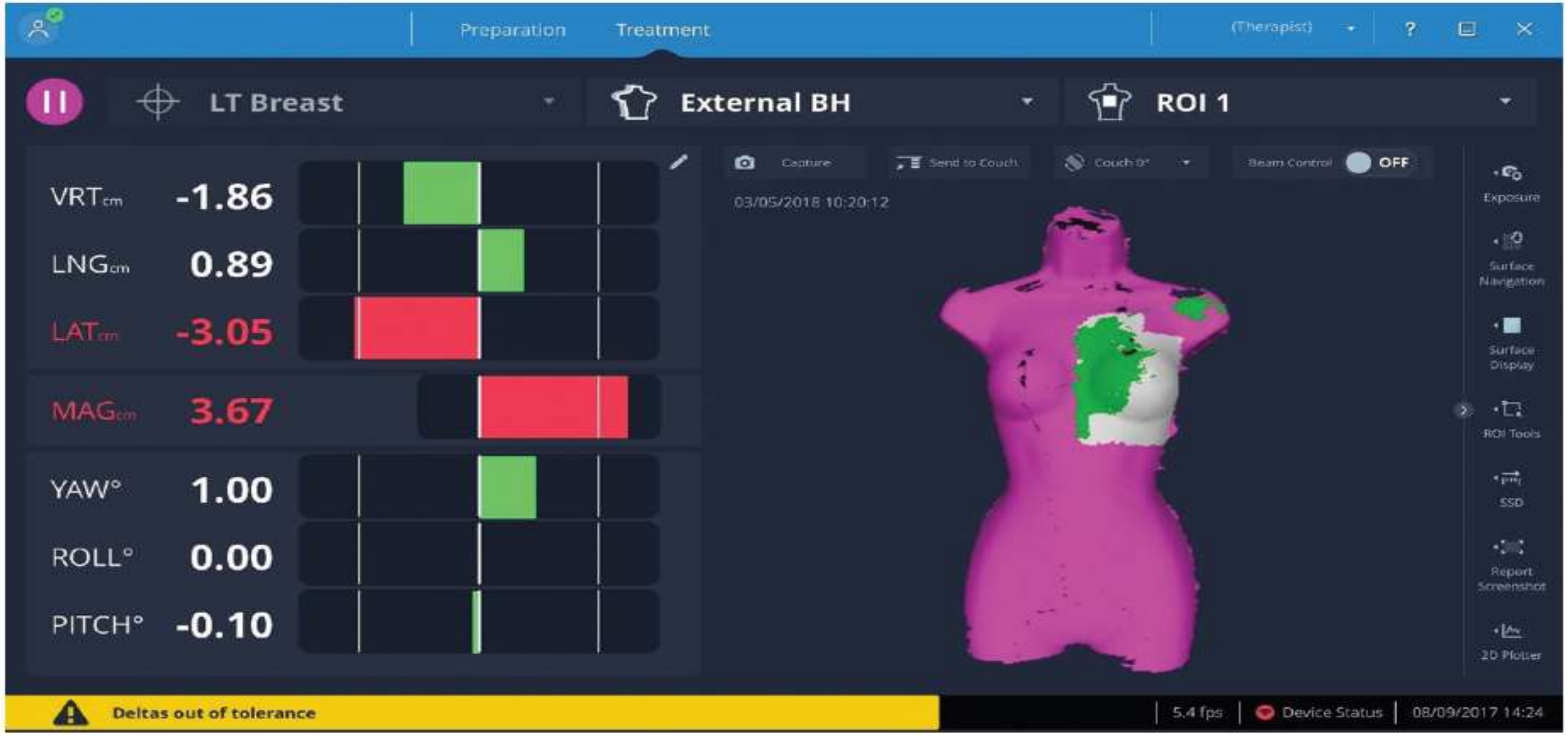


The real-time surface is aligned with either a surface model of the patient that was generated from the treatment planning CT scan or a surface that was previously captured by the AlignRT system itself

Surface reconstruction : Like human visual system, AlignRT uses stereo vision concepts to generate 3D information,

Surface Registration: by Rigid registration

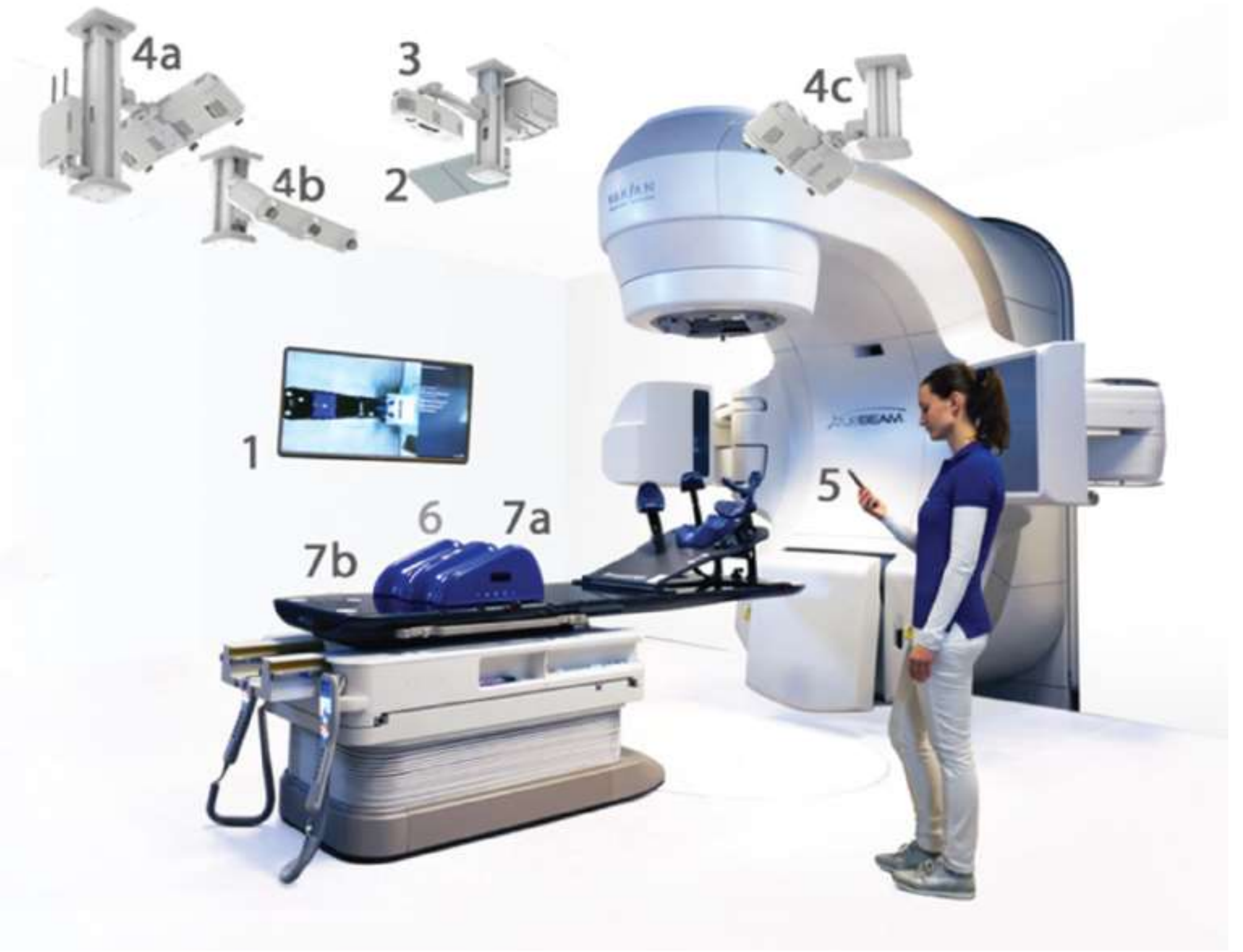
Surface matching results are displayed to the users as a series of 6DOF rigid shift values, known as real-time deltas (RTDs



IDENTIFY SYSTEM (BY VARIAN)

TABLE 4.1 IDENTIFY System Components—Detailed Listing

No.	Description
1	*In room monitor* Displays the patient ID, patient photo, setup photos, setup accessories, patient surface image for setup on couch top, supplemental respiration coaching signal
2, 6	*RFID reader and antennas, RFID tagged device* Detects patient (optional) and RFID tagged set up devices on the couch top
3	*Orthopedic setup time-of-flight camera system* Tracks the position of set up devices and the initial head to toe set up position of the patient on the couch top
4 a, b, c	*3D surface imaging camera system* Tracks the position of the patient at isocenter, utilizing a specified region of interest for interfraction positioning, intrafraction motion and respiration monitoring
5	*Handheld controller* Portable, wireless handheld controller for acquiring patient and setup photos, and for interacting with IDENTIFY
7a	*Position marker* This is used for on-couch top device position verification
7b	*Table reference position marker* Used to determine the position of the accessories relative to the reference marker



TIME OF FLIGHT CAMERA

Tof camera systems consist of an image sensor, a modulated light source, and a computer processor.

Tracks the position of set up devices and the initial head to toe set up position of the patient on the couch top

ToF cameras measure the time taken for photons from the projector to travel to the object and return to the detector. The distance traveled by reflected photons is determined by computing their phase shift from the original modulated source.

ToF cameras illuminate an entire scene simultaneously and do not require physical or electronic scanning or a second camera as with stereophotogrammetry.

OTHER PODS ARE USED AS THE SAME WAY AS OF STEREOVISION TECHNOLOGY

C-RAD SYSTEM

The Sentinel : laser surface scanning system

The Catalyst: consist of one or three optical surface imaging cameras

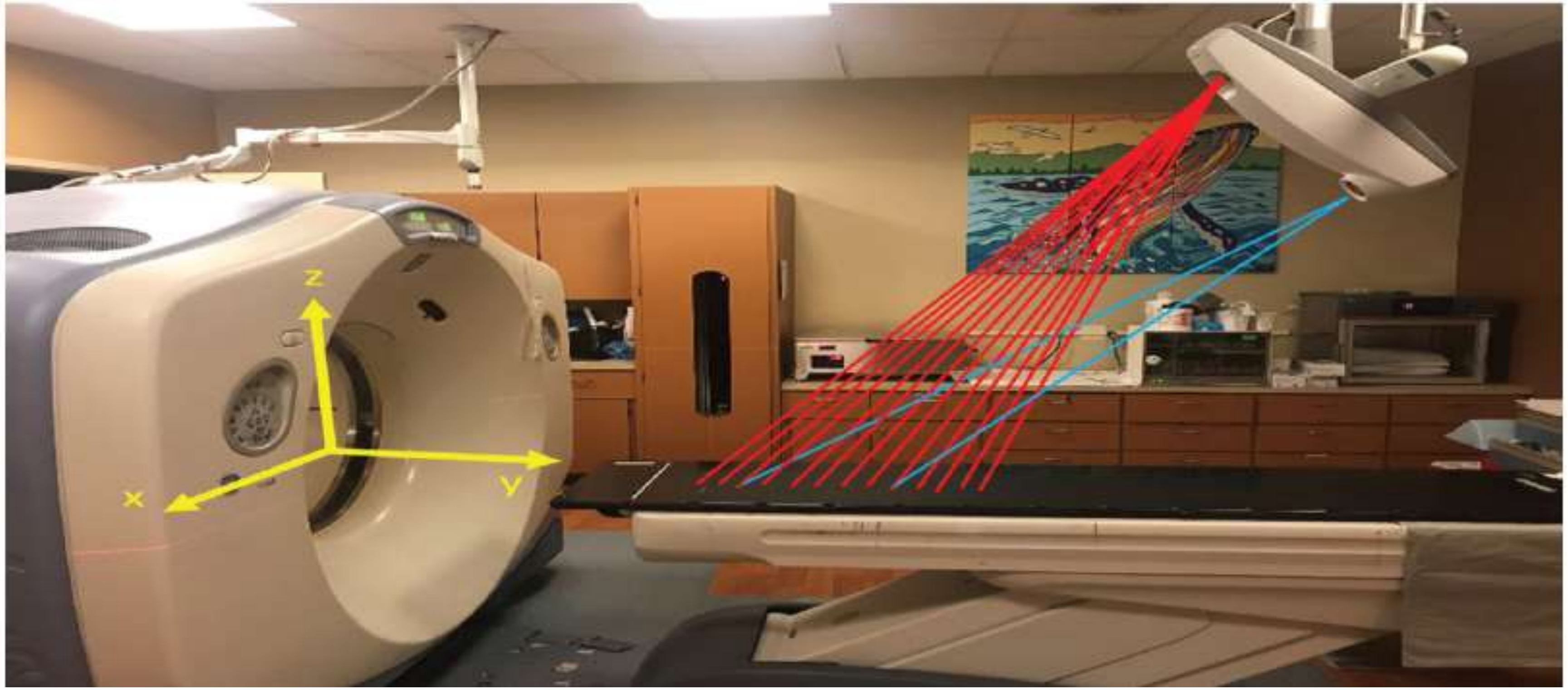
ceiling-mounted in the radiotherapy treatment room and are used to assist with patient setup, positioning, and motion monitoring during treatment delivery

LASER BASED SCANNING

The Sentinel scanning unit consists of a red line laser and a rapidly rotating mirror, or galvanometer, powered by an optical fiber connected to the computer.

As the galvanometer projects laser lines on to the surface of the target, part of the light is reflected back to the Sentinel system.

charge-coupled device (CCD) camera detects the reflected light. Known angles of the laser light and reflections are used to produce a 3D surface image of the object through a triangulation technique.



ESTRO-ACROP guideline on surface guided radiation therapy

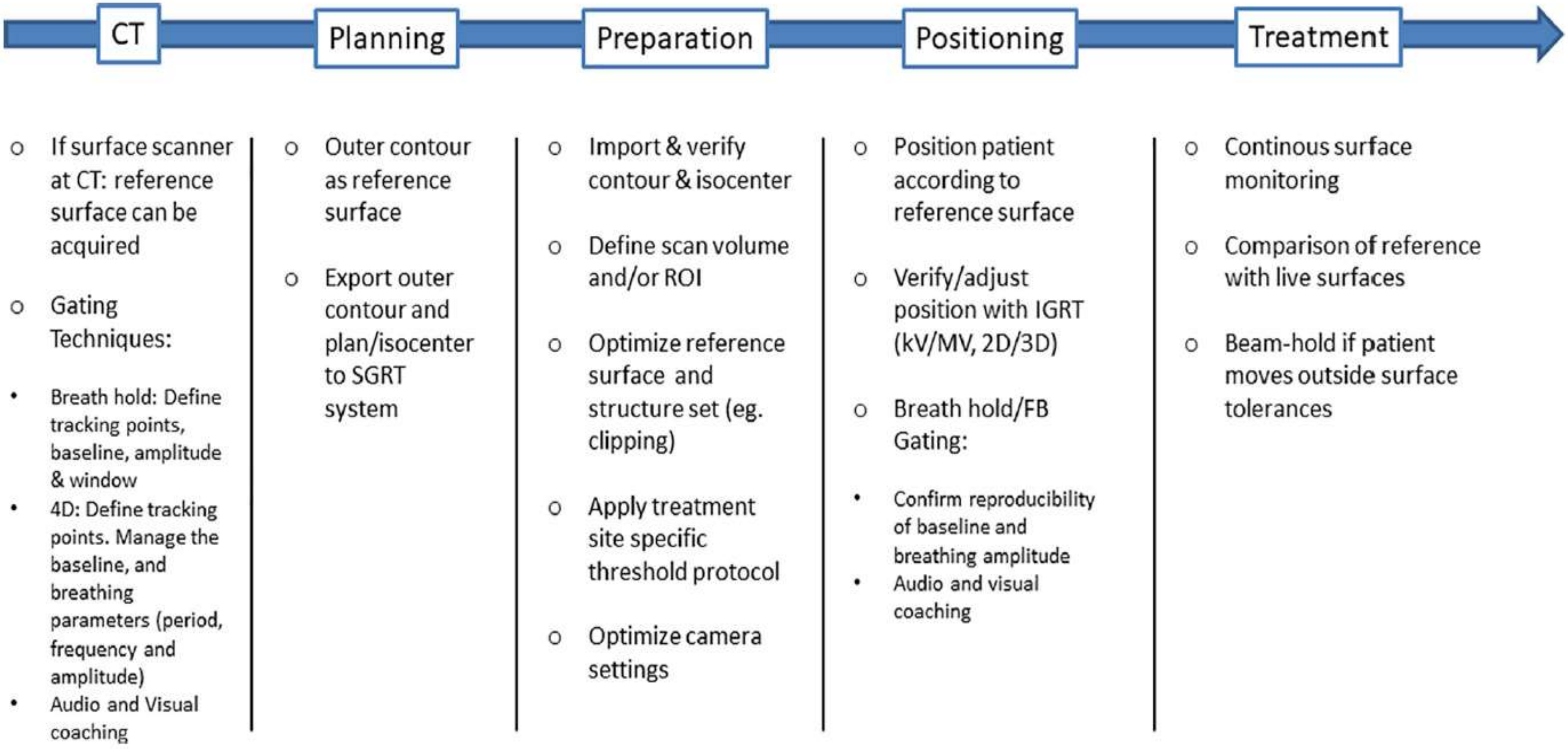
P. Freislederer [a,1,*], V. Batista [b,c], M. Öllers [d], M. Buschmann [e], E. Steiner [f], M. Kügele [g], F. Fracchiolla [h], S. Corradini [a], M. de Smet [i], F. Moura [j], S. Perryck [k], F. Dionisi [l], D. Nguyen [m], C. Bert [n], J. Lehmann [o,p,q]

- SGRT implementation should be led by a core multidisciplinary team (MDT), usually consisting of radiation therapists (RTTs), medical physics experts (MPEs) and radiation oncologists (ROs).

- Each institution should establish guidelines for staff responsibilities, which may vary between institutions and countries,

- A SGRT workflow is vendor- and clinic-specific, some concepts and steps are common in each SGRT application

- Continuous motion monitoring can be carried out in all the systems during the fractions


CT
Planning
Preparation
Positioning
Treatment
If surface scanner at CT: reference surface can be acquired
Gating Techniques:
Breath hold: Define tracking points, baseline, amplitude & window
4D: Define tracking points. Manage the baseline, and breathing parameters (period, frequency and amplitude)
Audio and Visual coaching
Outer contour as reference surface
Export outer contour and plan/isocenter to SGRT system
Import & verify contour & isocenter
Define scan volume and/or ROI
Optimize reference surface and structure set (eg. clipping)
Apply treatment site specific threshold protocol
Optimize camera settings
Position patient according to reference surface
Verify/adjust position with IGRT (kV/MV, 2D/3D)
Breath hold/FB Gating:
Confirm reproducibility of baseline and breathing amplitude
Audio and visual coaching
Continous surface monitoring
Comparison of reference with live surfaces
Beam-hold if patient moves outside surface tolerances

CT simulation

An SGRT system at the CT simulator can be used for breath-hold monitoring during CT acquisition, for patient coaching and, with some systems, to create a SGRT reference surface. Additionally, some systems offer the possibility to use the respiratory motion signal as a surrogate to reconstruct a respiratory-correlated CT (4DCT)

SGRT camera can be mounted for taking body surface during CT scan . But here number of camera required just only one .

For Breath Hold :
Minimum breath hold time for CT acquisition, normally 15–20 seconds
Minimal amplitude (>1 cm) from breath hold to breathing baseline
Patient able to communicate and to see and/or hear the instructions throughout the procedure

But in maximum system SGRT only mounted in radiotherapy room. DICOM format get transferred from planning system to the radiotherapy SGRT system.

4D CT ACQUISITION BY GATE CT @R

a single centrally located stereoscopic camera system, typically calibrated to the center of the CT scanner’s central imaging plane
.

• The system uses an integrated gating controller (IGC) or external X-ray detector to interface with most vendor’s CT scanner in order to synchronize the data to the completed 4D-CT scan.

• The system is used to characterize and record a patient’s respiratory motion by monitoring a point and/or region, sometime referred to as a patch, on the 3D reconstructed surface of the patient as they move through the CT scanner.

The respiratory-synchronized information obtained by tracking the patient’s surface during a 4D-CT scan is then exported to the CT vendor’s proprietary platform and 4D-CT reconstruction done

Reconstruction done by Retrospectively correlated CT scans are considered to be the closest thing to a “true” 4D-CT scan as the entire respiratory cycle is typically captured during the CT simulation.

Contouring and Planning

Outer contour as reference surface

IF DIBH, then both free breathing and DIBH scan registered in SGRT system at radiotherapy room

Export outer contour and plan/Isocentre

If you dont have SGRT camera at CT simulator then you have to import the outer contour as DICOM from TPS

PREPARATION

Import and verify contour and Isocentre

SELECTION OF REGION OF INTEREST (ROI)

Most crucial part of SGRT

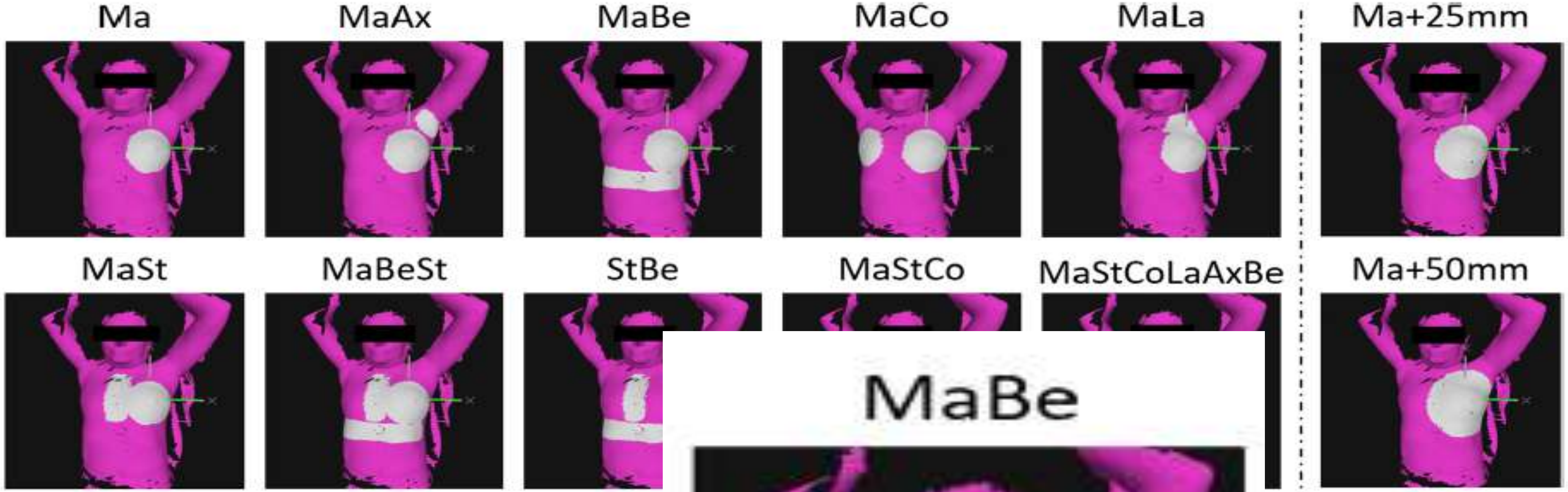
good representation of target motion,

unique topographic features and not include immobilisation devices.

ROI should consider couch rotation uses, and possible camera blocking-effects

Region of interest optimization for radiation therapy of breast cancer

Tim-Oliver Sauer | Oliver J. Ott | Godehard Lahmer | Rainer Fietkau | Christoph Bert



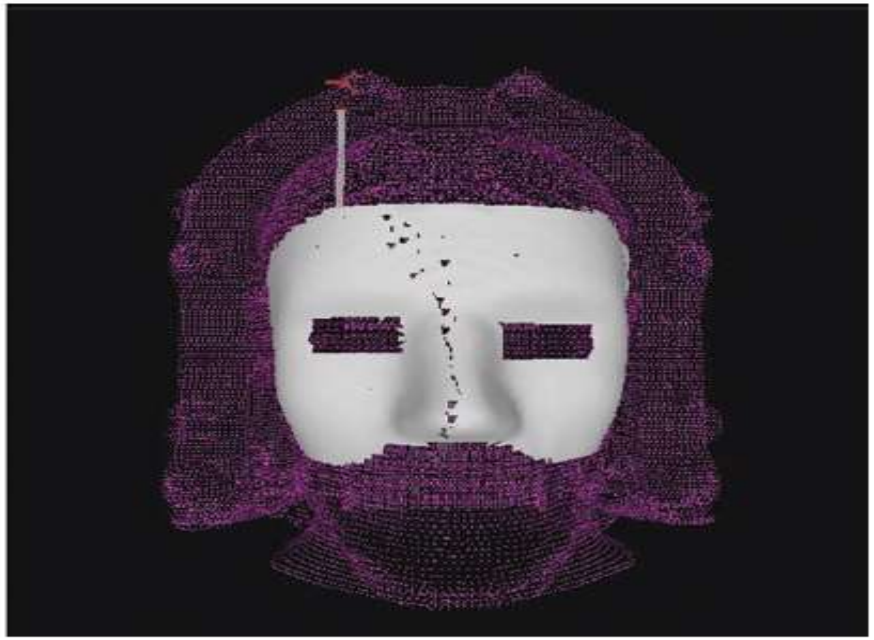
minimizing the deviation to the clinically applied CBCT shifts

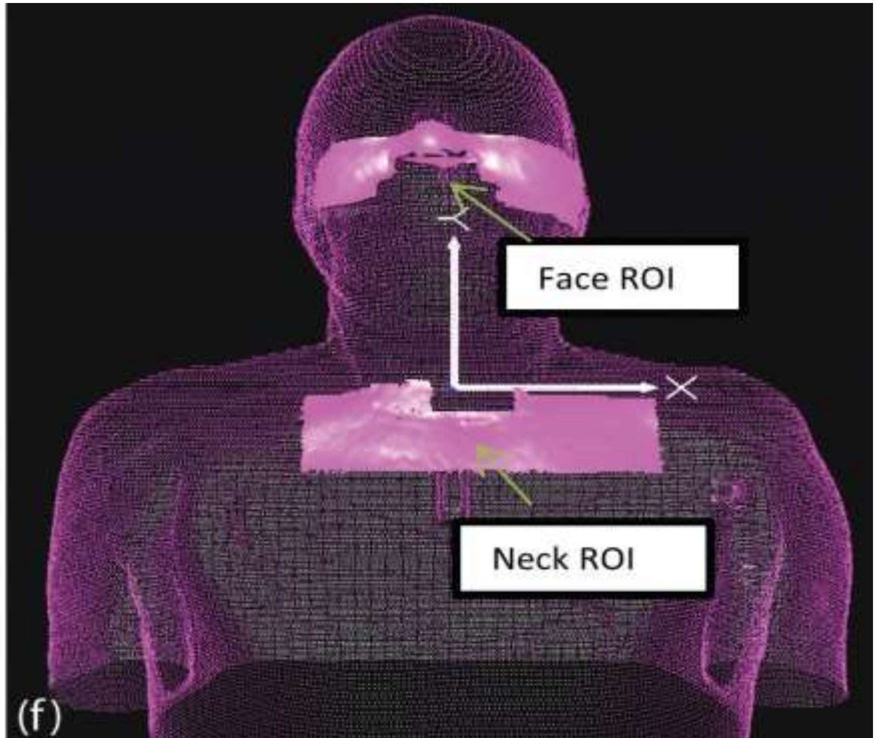
use of an ROI comprising the surface of the breast, sternum, and a belt underneath both breasts for SGRT breast cancer patient positioning and monitoring.

Use of bolus should be carefully considered, bolus material may be ''invisible'' for the surface scanner

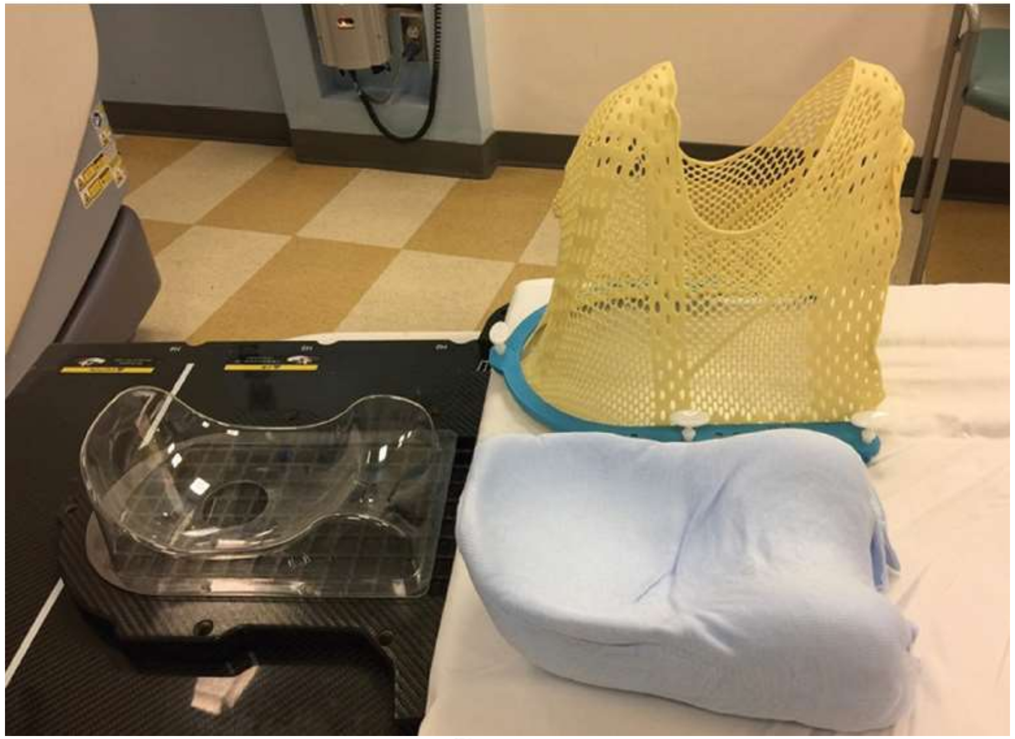
To make the bolus non glossy, so that it can be easily detected by the SGRT pods

HEAD NECK



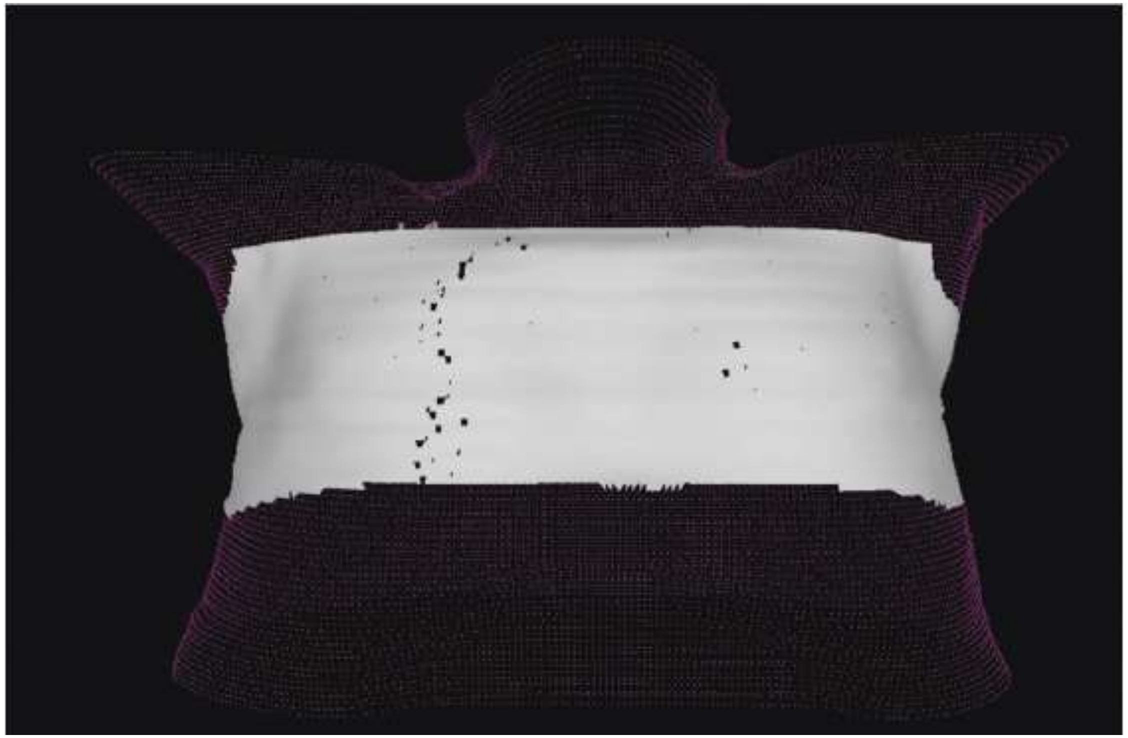


SRS OR FSRT

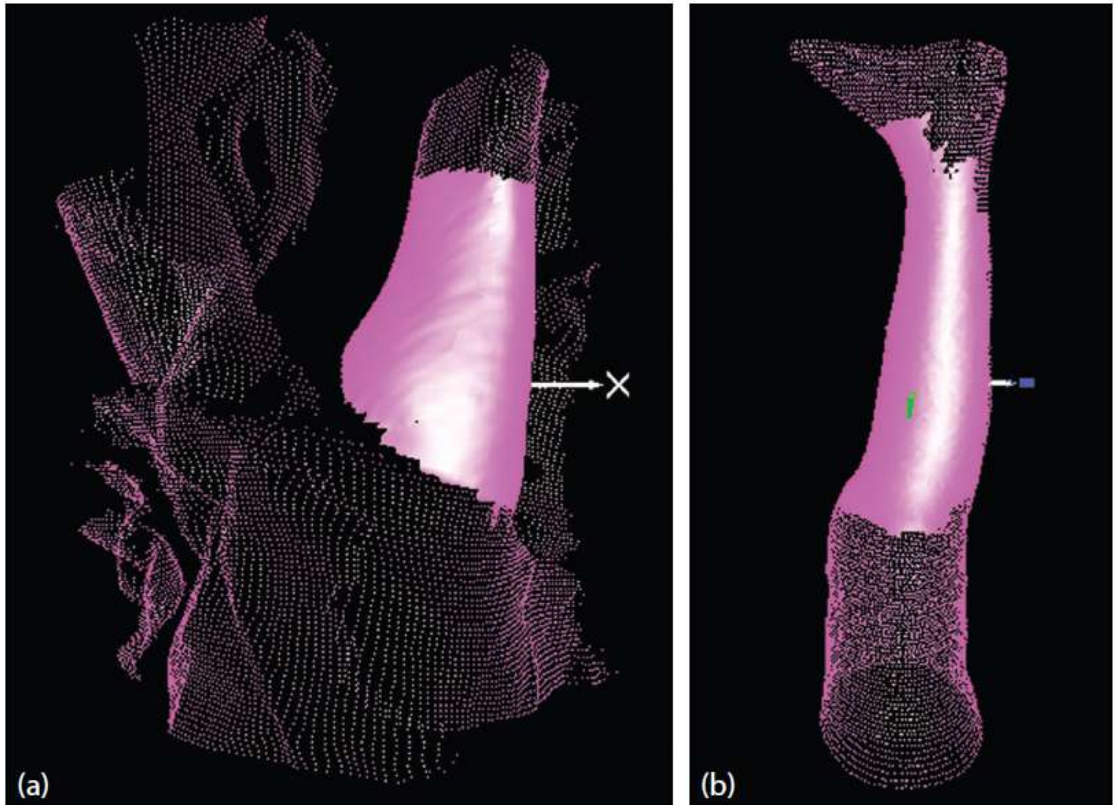


Avoid anatomy subject to involuntary or local motion (e.g., jaw, mouth, eye, or eye brow motion

LUNG SBRT



SARCOMA



Confirm that none of the SGRT camera pod(s) are blocked by gantry/couchrotation/panels for reference surface acquisition or during treatment (before the treatment start) (checklist to identify the cases, optimise the ROI)

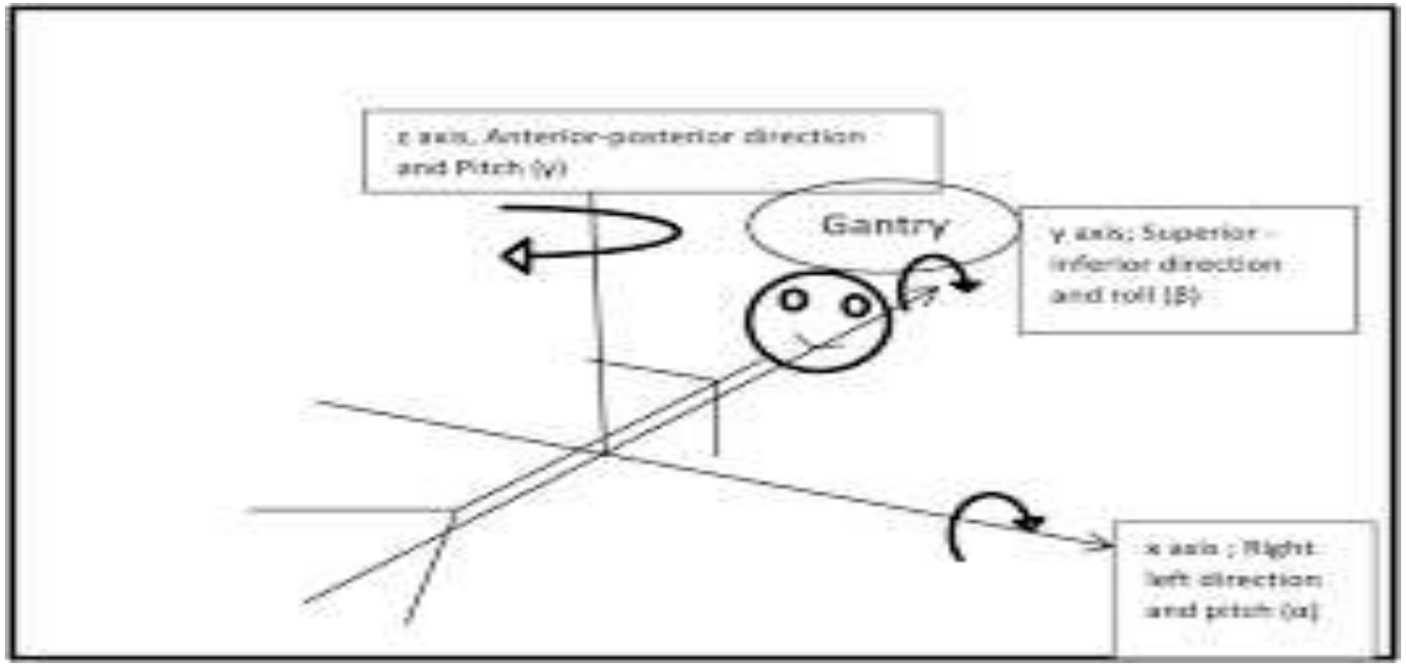
Positioning done by Isocentre detected as in SGRT system

SGRT positioning must be verified by independent IGRT (kV and/or megavoltage (MV), 2D or 3D)

If there is shift then new reference surface is acquired, this should be done only with IGRT verification (kV, MV, or cone beam computed tomography (CBCT), according with the site-/application-protocol)

Use motion monitoring: Treatment should be interrupted if the patient moves out of tolerance, ideally automatically.
If a patient does not move back in the original position by themself, repositioning with SGRT/IGRT.

6 Degree of Freedom (DOF) and Delta
: 3 ROTATIONAL (pitch, roll, yaw)
AND 3 TRANLATIONAL SHIFT (x, y, z)



Magnitude value : calculated as the square root of the sum of the squares of the three translational RTD values.

This information can be used to adjust the patient's position or to otherwise make clinical decisions based on the patient's real-time position.

The all DOF threshold to be preset . Any deviation from the threshold there will be beam off

For subsequent Day treatment :

Set up the patient according to the previous day reference capture.

A defined protocol for frequency of SGRT & IGRT combination should be used.

In cases without daily IGRT, SGRT should be verified by IGRT at least weekly.

Anatomical changes over treatment should be monitored. If changes are observed these should be investigated before simply acquiring a new reference surface

SGRT APPLICATION IN BREAST CANCER

Deep Inspiratory Breath Hold

Enough time for training with the patient should be allocated

Visual/audio feedback for the patient is advisable

Minimum breath hold time for CT acquisition, normally 15–20 seconds

Minimal amplitude (>1 cm) from breath hold to breathing baseline

Import both free breathing and DIBH CT in the system

Different reference surfaces for free breathing & inspiration might be used; ROI drawn over free breath and DIBH.

Set up done by the Isocentre data from TPS. Correction of baseline shift should be performed and verification by IGRT

The baseline shift is dependent on the reference surface of the day and needs to be adapted on a daily basis to account for interfractional changes

Rtts to instruct the patient to take deep breath . And respiratory movement threshold (±2.5mm) when achieved the treatment start
Rtts have to set the preset threshold of accepting the variation of DOF during treatment.

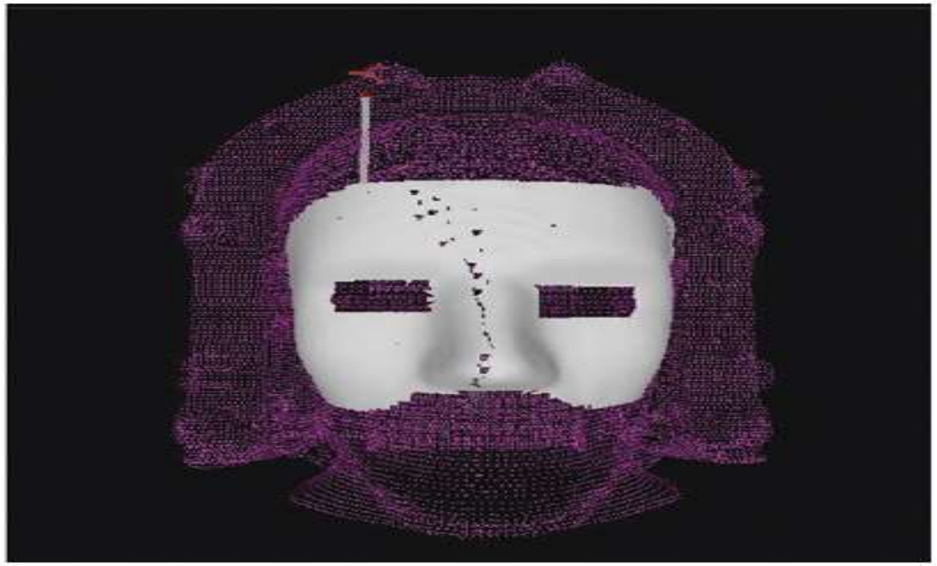
During the treatment if any DOF cross the preset threshold value , beam stopped.

For the subsequent day treatment the first day reference image(post IGRT verification) to be considered,

Variation between original baseline and the daily treatment (>5mm), consider IGRT verification for further baseline update.

All types of adjustments and corrections, require previous- and post- IGRT verification.

SGRT APPLICATION IN SRS

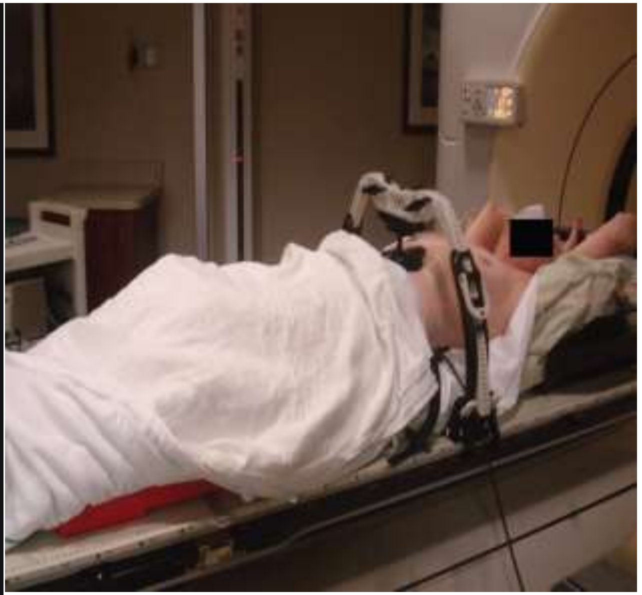


SGRT system are within tolerance (usually below 1 mm for translations
and 1° for rotations

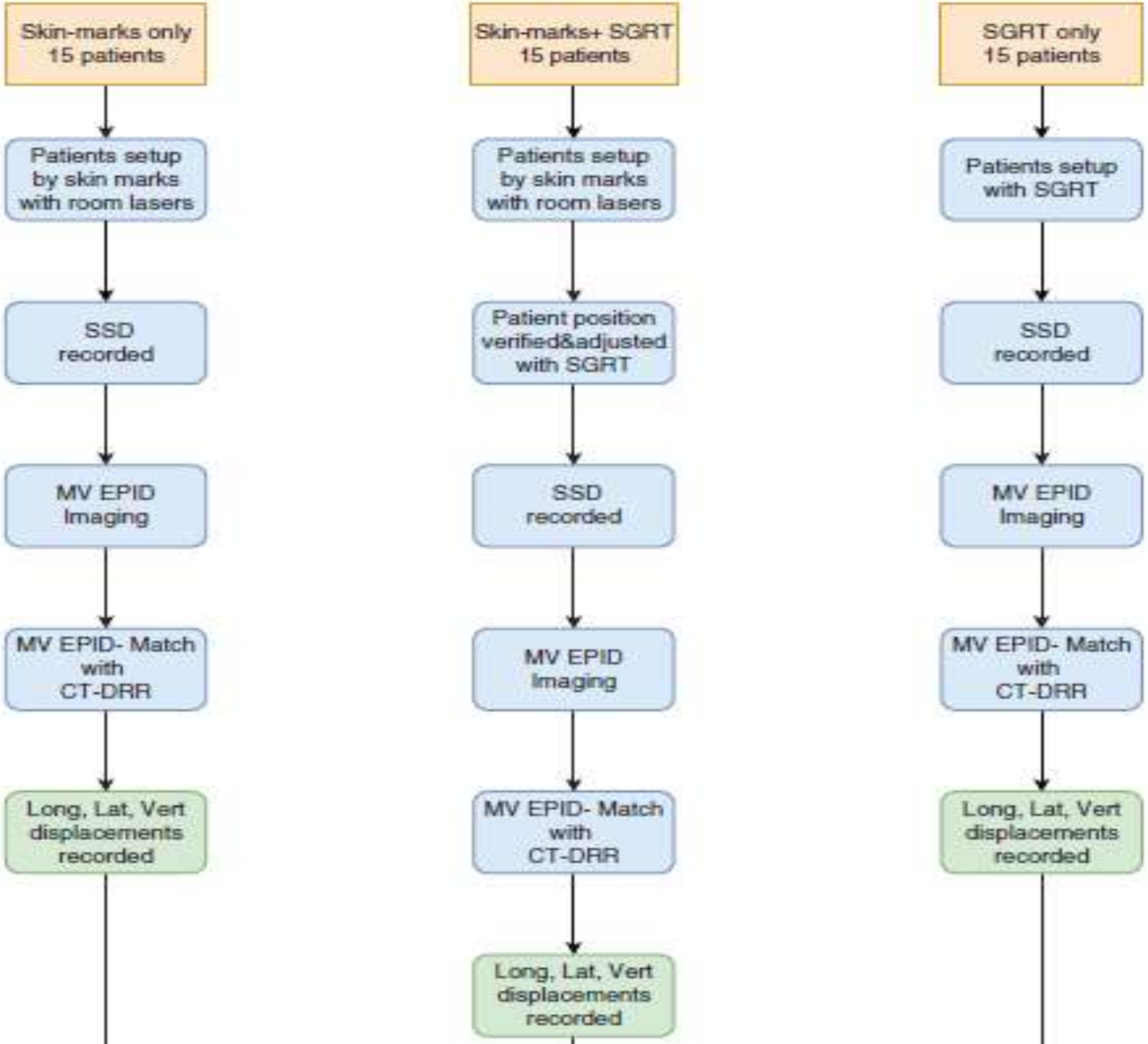
SGRT APPLICATION IN SBRT

Obtaining 4D CT scan using SGRT

Using SGRT for Intrafraction motion assessment



Skin Mark-Less Patient Setup



Patient Self-Occlusions:

•**Phantom Breasts and Body Morphology:** Patient self-occlusions can occur due to the presence of phantom breasts or body morphology, which can obstruct the SGRT system's ability to track the surface.

• **Reliance on Vendor-Specific Methods and Training:**

•**Vendor Dependence:**

•SGRT systems are often highly dependent on vendor-provided methods, training, and quality assurance.

•**Cognitive Load:**

•Implementing a new technology like SGRT can create a significant cognitive load for the clinical team, requiring adequate time for learning and assimilation.

Uncertainty in Patient Positioning:

•**Uncertainty in Internal Anatomy Correlation:**

•SGRT systems only image the external surface, and the correlation to the internal anatomy can be uncertain.

: Using an improper reference surface or baseline can also lead to errors.

Sensitivity to External Factors:

•**Ambient Light and Reflectivity:**

•The effectiveness of SGRT systems can be affected by ambient light and reflectivity, potentially compromising scan quality and image reconstruction.

•**Light Attenuating Surfaces:**

•Darker skin tones or body hair can compromise image registration due to limited visibility of the projected pattern.

•**Mismatch between SGRT or kV/MV/Radiation Isocenters:** A mismatch between the SGRT or kV/MV/radiation isocenters can also lead to errors.

Challenges with Intra-Bore Motion Tracking:

•**Limited Lateral Surface Coverage:**

•SGRT systems can have difficulty tracking patient motion within the treatment bore due to limited lateral surface coverage.

•**Poor Surface Qualities:**

•The surface qualities within the bore may not be ideal for 6-degree-of-freedom (6 DOF) patient motion tracking.

HIGH COST

TAKE HOME MESSAGE

- Surface Guided Radiotherapy (SGRT) is a technique used to ensure accurate patient positioning during radiation treatment by monitoring the surface of the body.
- Enhances **treatment accuracy** and **patient safety**
- Enables **real-time motion tracking** for better precision
- Reduces the need for **tattoos and immobilization**
- Improves **workflow efficiency** and **patient comfort**
- **Future Scope:** Integration with **adaptive radiotherapy,** Advancements in **AI-driven motion tracking**

A Step Towards Safer & More Precise Radiotherapy

THANK YOU