AlignRT

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Experience and Technical Challenges in Acquiring and Using a SGRT System. Benefit of SGRT Positioning & Intra-Fraction Monitoring Based on Mobius Data

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- My comments and the accompanying slides reflect my own opinions and are not necessarily those of VisionRT or my institution.
- Legal rights, including any patient consents, to the information or materials being presented have been secured by me.
- No conflicts of interest to report

The contribution of uncertainties in the final dose delivered to the patient

* 1 %-2% dose absorbed in water under reference conditions

Reference dosimetry

TPS

* 2 % dose distribution calculation (individual)

* 2 % positioning the patient (or the source in the patient)

Patient positioning

IGRT

Organs movements

* 3 % tumor movement during or between treatment fractions

* 2 % the precision of radiation beam

LINAC

TARGET: TO APPLY THE TOTAL DOSE IN THE TUMOR VOLUME WITH MAXIMUM 5% DEVIATION!

Imaging guided radiotherapy(IGRT)

How can we identify the position of the target?

- Image-base RT – used to define target and OAR : MRI, PETCT ….
- Image-guided RT – use of imaging for monitoring and adapting treatments

IGRT Technology Solutions

- Depending on the imaging methods used, the IGRT systems may broadly be divided into two groups:

Non-Radiation Based Systems

- Ultrasound based systems
- Camera-based systems
- Electromagnetic tracking,
- MRI based systems

Radiation Based Systems

- Electronic Portal Imaging Devices (EPID)
- Cone Beam CT (CBCT) – KV or MV
- Fan Beam KV CT (CT-on-Rails)
- Fan Beam MV CT (TomoTherapy)
- Exac-Trac X-Ray 6-D Stereotactic IGRT System
- Hybrid Systems for Real Time 4D Tracking
  - ✓ 2D KV Stereoscopic Imaging (Cyber-Knife)
  - ✓ Real Time Tumor-Tracking (RTRT) System.
  - ✓ VERO system

How it works?

- SGRT systems use optical imaging to register real-time (>1 frame/s) 3D surfaces of a patient to a reference surface
- reference surface (based on CT SIM) is defined relative to the treatment isocenter
- SGRT algorithms calculate the translations and rotations in 6 degrees-of-freedom (6DOF) necessary to correct the patient's position in real time
- geometric accuracy is 1-2 mm, but application is limited only to situation where external surface may act as a reliable surrogate for internal position or motion

Looks easy but …

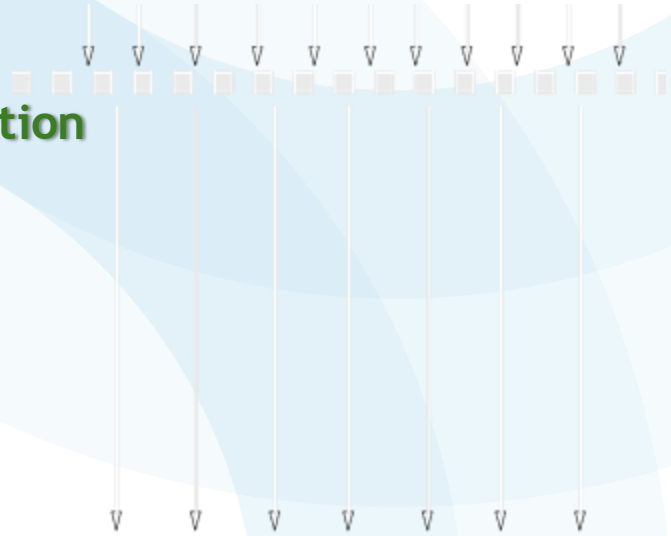
- 2019, Padilla et al. conducted an electronic survey to identify the necessity of formal guidance and to gain more insight on prevalence of the SGRT system, length of its use, existing recommendation for commissioning procedures and clinical implementation

- in 2022, an international survey was conducted with the collaboration of ESTRO and AAPM to provide an Quality Assurance Program for Surface-guided Radiation Therapy overview about the current status of SGRT in clinical practice with a focus on the user's experience in terms of implementation, commissioning, periodical quality assurance (QA), training, and clinical workflow

Results

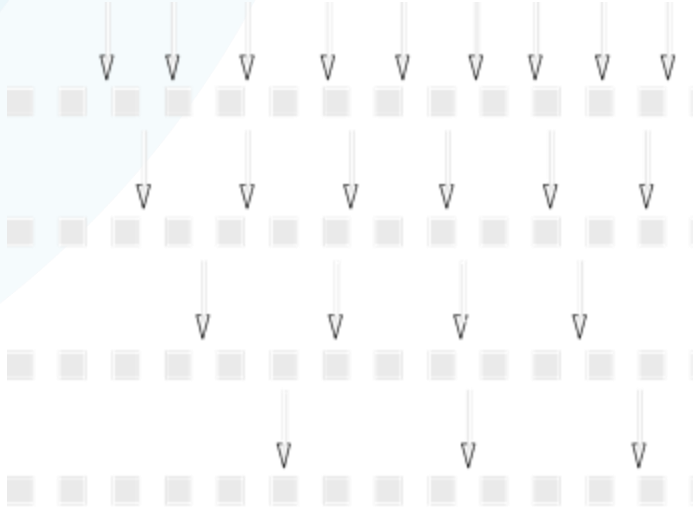
Clinical implementation of the SGRT systems was predominantly based on the vendor's recommendation

vendor's recommendation



safe and efficient ?

vendor's recommendation



Independent comprehensive quality assurance (QA) program including commissioning, acceptance and periodic QA

safe and efficient !!!

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AAPM SCIENTIFIC REPORT

MEDICAL PHYSICS

AAPM task group report 302: Surface-guided radiotherapy

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Guidelines

ESTRO-ACROP guideline on surface guided radiation therapy

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Table 2
Main parameters to include in an acceptance protocol, divided by type of equipment (x – mandatory, o – optional, pass – within Vendor's system specifications). For a full description of each test and respective alternatives consult the test description in Appendix III.

Acceptance			Specification/Tolerance	CT	C-arm linac	Closed-Bore linac	Particle Therapy
Parameter	Label	Test					
Static Accuracy	A1	Isocentre – Agreement between SGRT-isocentre and other isocentric-systems	1 mm/1°	x	x	x	x
	A2	Translational shift – Agreement between introduced and detected shifts in each direction	1 mm (up to 5 cm shifts)/ 2 mm (>5 cm shifts)	-	x	x	x
	A3	Rotational shift – Agreement between introduced and detected rotation in each direction	1°	-	x	x	x
	A4	Impact of camera occlusion – Introduced shifts when one or more camera pods are blocked (for the range of ROI clinically to be used)	1 mm/1°	-	x	x	x
	A5	Couch rotation – Integration & Basic	pass; 1 mm, 0.5°	-	o	-	x
	A6	Setup/loading position – confirm the system calibration at a non-isocentric position (when this option is part of the system)	1 mm/1°	o	-	o	o
Dynamic Accuracy	D1	Beam-Hold performance, AAPM TG 142 [28] – functionality and dosimetric (stationary dose point)	pass/2%	o	x	x	x
	D2	Tracking performance – Ability of the system to correctly measure translations and/or rotations of a moving object	1 mm/1° SRS: 0.5 mm/0.5°	x	x	x	x
	D3	Respiratory trace – Detectability of amplitude, frequency, shape variations.	pass	x	o	o	o
	D4	Trigger performance – Phase correct triggering and data reconstruction	pass	x	-	-	-
	D5	Frame-rate impact	pass	x	x	x	x
End-to-End Positioning	E1	End-to-end positioning test – Verify the entire workflow	2 mm-/1°	-	x	x	x
System performance	P1	Thermal drift – Impact of temperature on the camera performance [29]	1 mm/1° (20 min after 20 min in stand-by)	x	x	x	x
	P2	Room-light impact – Influence of the light level on the system accuracy	0.5 mm/1°	x	x	x	x
	P3	Field-of-view -Basic	pass	x	x	x	x
	P4	Quality of acquired surface image	pass	x	x	x	x
	P5	Integration – System interface with all peripheral systems	pass	x	x	x	x
	P6	Patient-Interface (Visual or audio)	pass	x	x	x	x
Safety	S1	Interlocks – existence and performance	pass	x	x	x	x
	S2	Data import & export	pass	x	x	x	x
	S3	Database Backups & security	pass	x	x	x	x
	S4	System configuration – Users Right & Pre-sets	pass	o	o	o	o
	S5	Mechanical Integration – Confirm integrity/Collisions	pass	x	x	x	x
Documentation	R1	Export patient- & QA- reports	pass	x	x	x	x
	R2	User manuals	pass	x	x	x	x

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Acceptance

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Table 3
Suggested parameters to consider during the system commissioning. These can vary with the installation and with the SGRT-applications and product. Some tests might already have been performed during acceptance and are listed here for completeness in italic (#) – include other aspects not evaluated at the acceptance stage (x – mandatory, o – optional, pass – for a specific indication and application the system is accepted for clinical use). Different levels of testing might be required depending on the application (i.e. Basic, Advanced, Radiographic, …) consult the test description in Appendix III for details.

Commissioning Parameter	Label	Test	Specification/ Tolerance	CT	C-arm linac	Closed-Bore linac	Particle Therapy
Static Accuracy	A1	Isocentre – Radiographic	1 mm/1° SRS: 0.5 mm/0.5°	-	x	x	x
	A2	Translational shift – Basic & Advanced	1 mm	x	x	x	x
	A3	*Rotational shift – Agreement between introduced and detected rotation in each direction*	*1°*	-	*x*	*x*	*x*
	A4	*Impact of camera occlusion – Introduced shifts when one or more camera pods are blocked (for the range of ROI clinically to be used)*	*1 mm/1°*	-	*x*	*x*	*x*
	A5	*Couch rotation – Integration & Basic*	*pass; 1 mm, 0.5°*	-	*o*	-	*x*
	A6	*Setup/loading position – confirm the system calibration at a non-isocentric position (when this option is part of the system)*	*1 mm/1°*	*o*	-	*o*	*o*
Dynamic Accuracy	D1	Beam Hold performance – dosimetric	*2% or 2 mm/2% 95% (10% threshold)*	-	x	x	x
	D2	Tracking Performance – FB-Gating Check, Lag Time	*200 ms*	-	o	o	x
	D3	*Respiratory trace – Detectability of amplitude, frequency, shape variations.*	*pass*	*x*	*o*	*o*	*x*
	D4	Trigger performance	pass	o	*o*	*o*	*o*
	D5	Frame-rate impact	pass/application	x	x	x	x
End-to-End Positioning	*E1*	*End-to-end positioning test – Verify the entire workflow*	*2 mm-/1°*	-	*x*	*x*	*x*
Special Techniques	X1	Extension of the FOV	pass	-	o	o	*o*
System performance	*P1*	*Thermal drift – Impact of temperature on the camera performance (tolerance applies for clinical situation, including clinically expected cool down periods)* (29)	*0.5 mm/1°*	*x*	*x*	*x*	*x*
	P2	*Room-light impact – Influence of the light level on the system accuracy*	*1 mm/1°*	*x*	*x*	*x*	*x*
	P3	Field-of-view – Advanced	pass	x	x	x	x
	P4	*Quality of acquired image*	*pass*	*x*	*x*	*x*	*x*
	P5	*Integration – System interface with all peripheral systems*	*pass*	*x*	*x*	*x*	*x*
	P6	*Patient-Interface (Visual or audio)*	*pass*	*x*	*x*	*x*	*x*
	P7	Registration-matrix Quality	pass	-	*o*	*o*	*o*
Safety	*S1*	*Interlocks – existence and performance*	*pass*	*x*	*x*	*x*	*x*
	S2	*Data import & export*	*pass*	*x*	*x*	*x*	*x*
	S3	*Database Backups & security*	*pass*	*x*	*x*	*x*	*x*
	S4	*System configuration – Users Right & Pre-sets*	*pass*	*o*	*o*	*o*	*o*
	S5	*Mechanical Integration – Confirm integrity/Collisions*	*pass*	-	-	-	*x*
Documentation	*R1*	*Export patient- & QA- reports*	*pass*	*x*	*x*	*x*	*x*
	R2	*User manuals*	*pass*	*x*	*x*	*x*	*x*

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Commisioning

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Table 4
Quality Assurance tests categorised by daily, weekly, monthly or annually periodicity. A – annually, M – monthly, W – weekly, D – daily, R – following repair or maintenance, O – optional.

Quality assurance			Frequency/Specification				
Parameter	Label	Specification	Recommended tolerance	CT simulator	C-arm linac	Closed-Bore linac	Particle Therapy
Static Accuracy	A1	Isocentre	1 mm/1° SRS: 0.5 mm/0.5°	D	D – Laser M- Radiographic	D	D
	A2	Translational shifts	2 mm	-	M	M	M
	A3	Rotational shifts	1°	-	M	M	M
	A4	Impact of camera occlusion	*1 mm/1°*		A\R	A\R	A/R
	A5	Couch rotation	1 mm/1° SRS: 0.5 mm/0.5°	-	M- Basic A – Radiographic	-	A/R
	A6	Setup/loading position	1 mm/1°	-	-	D	M
End to end positioning test	E1	End to end test	2 mm/1°	A/R	A/R	A/R	A/R
Dynamic Accuracy	D1	Beam hold performance	2% or 2 mm/2% γ = 95% (10% threshold)	-	A	A	A
	D2	Tracking performance – translations & Rotation & Couch-motion	1 mm	-	M/A	A	A
	D2	Tracking performance – rotations	1°	-	M/A	A	A
	D2	Tracking performance – with couch motion	1°, 1 mm	A	-	A	A
	D3	Respiratory trace	pass	D/M	D /M		D/M
	D4	Trigger performance	pass	A	-	-	-
System Performance	P1	Thermal Drift (clinical)	0.5 mm	A	A	A	A
	P3	Field of view – Basic/Advanced	pass*	A	A	A	A
	P4	Quality of acquired image	pass*	A\R	A\R	A\R	A\R
	P5	Integration – System interface with all peripheral systems	pass	-	-	-	-
	P6	Patient Interface	pass	D	D	D	D
Safety	S1	Interlocks	pass	M/A (If available)	M/A	M/A	M/A
	S3	Database backup & security	pass	A	A	A	A
	S4	System Configuration	pass	A	A	A	A
	S5	Mechanical Integrity	pass	D	D	D	D
Documentation	R3	QA-Documentation	pass	M/A	M/A	M/A	M/A

(*) when only visual inspection is possible, the comparison with the acceptance-reference should be done based on clinical criteria).

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QA tests

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Appendix I – List of failure modes and potential errors in SGRT workflows with possible solutions

Failure modes and errors		Specific situation	Possible solution
Workflow, insufficient training	Wrong reference used for treatments	Confusion of free breathing and breath hold surface	IGRT verification at least in the first fraction
		Recording a wrong reference and subsequently using it for treatment	Record new SGRT reference only with IGRT verification
		Treating and SGRT monitoring a different plan	Should be prevented by SGRT systems' inherent checks; IGRT verification; verify that the correct plan and reference are loaded on the linac and in the SGRT system
	Selection of the wrong isocentre	Selection of the wrong isocentre in case multiple isocentres are to be treated	IGRT verification; should be prevented by SGRT systems inherent checks
	Selection of wrong SGRT protocol for treatment site	Selection of wrong SGRT protocol (e.g. breast instead of SBRT) leads to wrong gating window/frame rate	Protocol should fit to site and treatment intend; establish department guidelines; check before first treatment
	Wrong workflow	Using the system for a workflow that is not intended by the vendor	Vendor training
	Wrong definition of ROI	Wrong location, unawareness of selection of wrong pixels, too small, not sensitive to motion	Training; establish department guidelines; check ROI before first treatment ideally using the 4-eye principle
	DICOM RT structure set variations	Different methods or settings for contouring body/outer contour leads to variations in the structures	Consistent settings documented and used
	Bolus used with SGRT	A bolus may be added in the RT planning process. Bolus material may be invisible for the surface scanner.	Use a reference surface without bolus for setup and then put on the bolus or use bolus material that is visible for the surface scanner.
	Gantry occlusions lead to loss of signal/signal deviation	Reference capture with gantry or kV and MV imager in the way leads to inaccuracies	New reference capture only when no occlusions are present (retract imagers)
Commissioning, calibration, QA	Wrong (isocentre) calibration	Calibration performed with a not accurate in-room laser	Check in-room laser first; perform calibration to MV isocentre
	Wrong interpretation of coordinate system & units	Axes: positive/negative? cm, mm?	Training; acceptance; commissioning
	Gantry occlusions lead to loss of signal/signal deviation	Occlusion through gantry depending on gantry and couch angle; kV and MV imager	Commissioning for determining gantry occlusion effects for various geometries

Tests recommended

Appendix III – Description of the recommended tests and different methodologies. These recommendations should be used as guidelines, as depending on the treatment-site, application, workflow and available-equipment each of these might need to be adapted.

Label	Test	Description
A1	Isocentre	**Agreement between SGRT-isocentre and other isocentric-systems (translations and rotations, if available)** Room-Lasers: Coincidence between SGRT and the room-lasers Radiographic: Coincidence between SGRT and the radiographic isocentre (kV or MV) A geometrical phantom is placed at the isocentre of the SGRT system (which would normally coincide with the isocentre of the treatment system) and the ability of the SGRT system to correctly identify this is quantified. Depending on the requirements of the test the setup can be made relative to the in-room laser system, the treatment isocentre as assessed by treatment beams, or relative to the imaging isocentre (e.g. setup with CBCT). For closed-bore linacs, the virtual isocentre (laser) cannot be easily adjusted by the user. Radiation isocentre calibration using MV is mandatory here (1).
A2	Translational shifts	**Agreement between introduced and detected shifts in each direction** Basic: Magnitude and each component. Reproducibility of consecutive measures. Detection of a small shift (mm-range) and large shift (cm-range). Advanced: Define a ROI at an Off-axis region (>10 cm), shifts performed from there. An appropriate phantom should be positioned on the couch at known distances from its correct isocentre position, as defined by a previously obtained reference image (either from CT or taken with the SGRT system, depending on workflow). This can be achieved using the lasers and markers on the phantom. The distances should be clinically realistic for the patient setup situation. (1-10 cm) The ability of the SGRT system to quantify the distances in all three directions should be assessed. For simplicity, this can be done in one setup using shifts in all six directions. Different shifts should be used in each direction to ensure the correct identification of directions. The ability to move the couch to the correct isocentre position can be also checked if the system is capable of sending the shifts to the patient positioning system.
A5	Couch rotation	**Agreement between couch angle as per machine and per SGRT system** Integration test: Create a treatment plan for any phantom and include beams with non-zero couch angles in both directions and at different positions (e.g. 90, 45, 30, 320, 270). Import the plan into the SGRT system. Open the plan at the machine and in the SGRT system and confirm the agreement between couch angles as per display in the machine and per SGRT system (for multiple angles). Basic: A phantom is placed at the linac couch at the room isocentre, an SGRT reference capture is acquired with the couch at zero degrees. The couch is then rotated to 45, 90, 315 and 270° (using the couch-reader angle) and the value is compared with the one from the SGRT software. (Depending on the SGRT system, this might require calling up the above created and imported treatment plan.) Besides angle, other coordinates should be checked as well. If a large variation is detected, confirm the accuracy of the couch-reader value, e.g. using an external measurement tool. Radiographic: A phantom with a dosimetric insert (e.g. film, array, etc.) is placed at the Linac couch at the room isocentre, an SGRT reference capture is acquired with the couch at zero degrees. The couch is then rotated to 45, 90, 315 and 270° (using the couch-reader angle or a more accurate tool and possibly via a treatment plan, as per above). At each couch-angle the dosimetric insert is irradiated, and the SGRT-displayed shift is documented. The dosimetric-profile is compared to the couch-0 profile. For each couch angle, the dosimetric shifts should be comparable to the SGRT-displayed-shifts. Possible inaccuracies of the treatment couch rotation should show in the profile shift and the SGRT-displayed shift in a similar way. Note: if the isocentre of the treatment room is defined with the isocentre of the X-ray imaging system, after the couch rotation an X-ray image is acquired, and the correction vector calculated by the patient positioning system is compared with the SGRT-displayed shift.

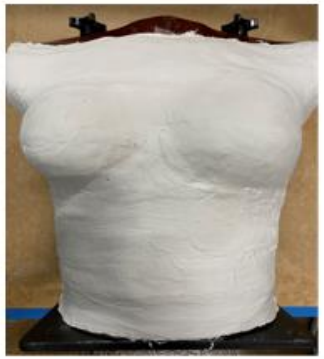
Appendix IV – Commercially Available Phantoms or user-customised dedicated to SGRT-testing

A. Phantom Requirements* *Depending on the performed test the set of important parameters affects the phantom selection	
Parameter	**Description of ideal characteristics**
Surface colour/texture	No reflecting effect, specific landmarks, uniform surface colour, different skin colour might also be available
Dosimetry	Possibility to use ionization chambers or film
Dynamic	Simulate a regular and irregular breathing signal (accuracy 0.3mm)
Positional	Possibility to move the phantom in translation and rotations with a minimal precision of 0.5mm, 0.5°
Thermal	Dedicated calibration phantoms, requirements defined by vendor
Radiographic	Internal structures visible with kV or MV-imaging, preferably with anthropomorphic structures

B. Commercially Available (Examples)

Name of the phantom	Illustration	Used in test	Main characteristics
Laerdal resuscitation phantom (Laerdal, Norway, https://laerdal.com/)		A2, A3, A4, P1, P2, P4	Hollow phantom with realistic skin tone. Dark skin tones are available as well. It can be used for translational and rotational, breath-hold and camera setting checks
Modus QA motion platforms ModusQA, London, Ontario, Canada https://modusqa.com/	 Image courtesy: ModusQA, London, Ontario, Canada	A2, A3, D1-4	Moveable motion platform with motorized motion axes and programmable motion patterns.

Phantoms

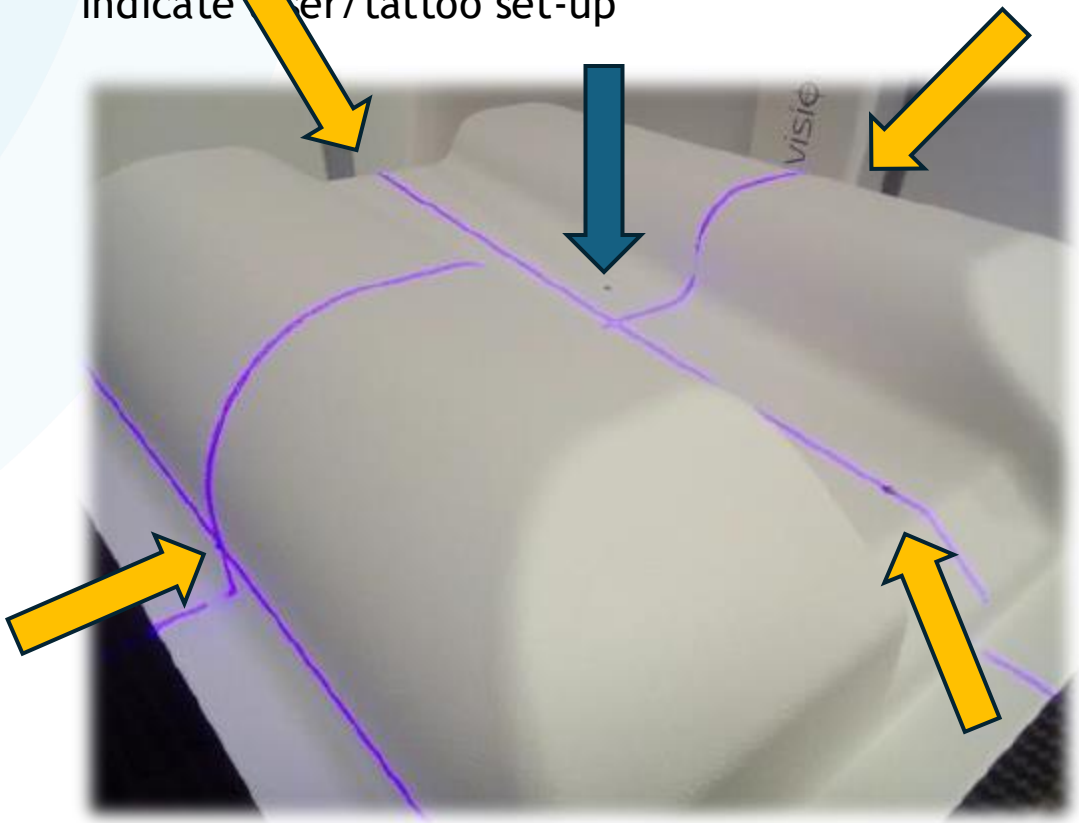
SRS face-doll with open-face mask		A1-5, D2 P7	Mannequin face-doll with realistic skin tone. It can be used for SRS applications and testing
Alderson phantom with a white thorax breast cast		A1-5	Female breast cast superimposed on the Alderson chest phantom
Breathing motion phantom		D1, D3	Thermoplastic mask material shaped to a thorax and deformed by stepping motor. Ball bearings for IGRT. Static ion chamber insert

Vertical movement - SimRT

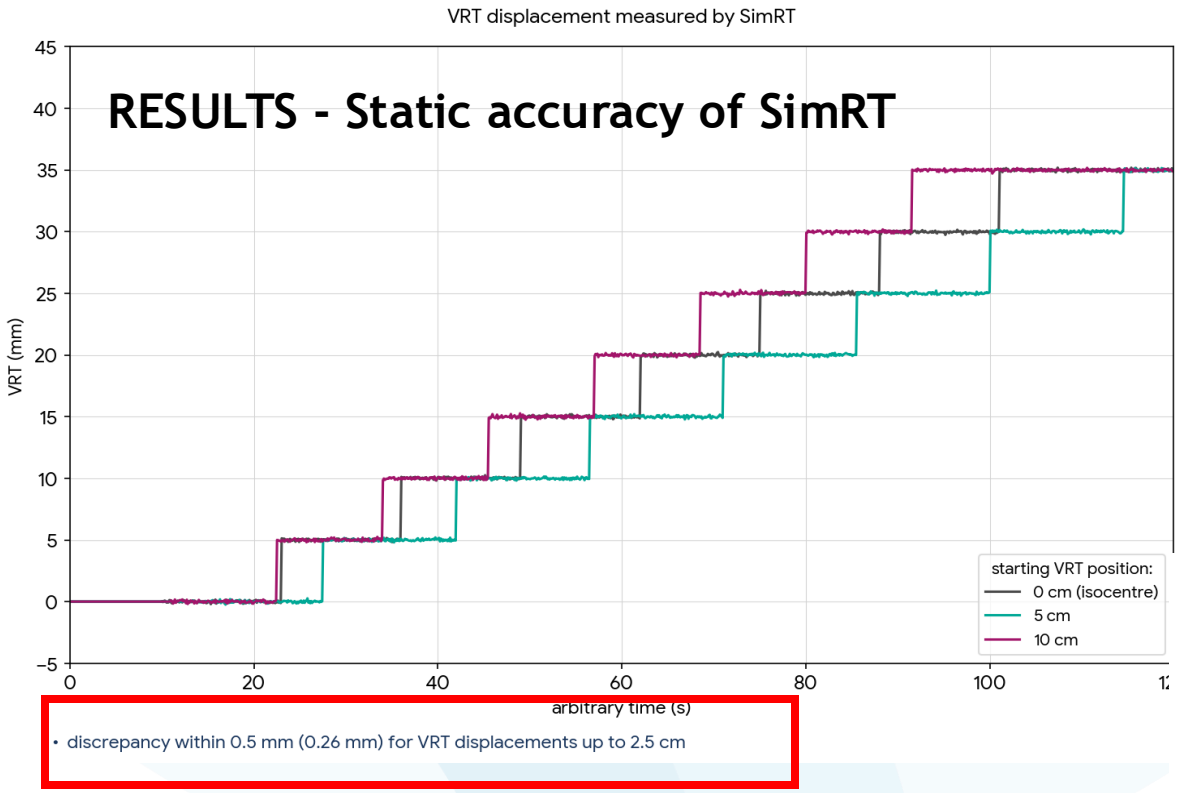
Static accuracy of SimRT (tolerance <= 1 mm ESTRO/ACROP):

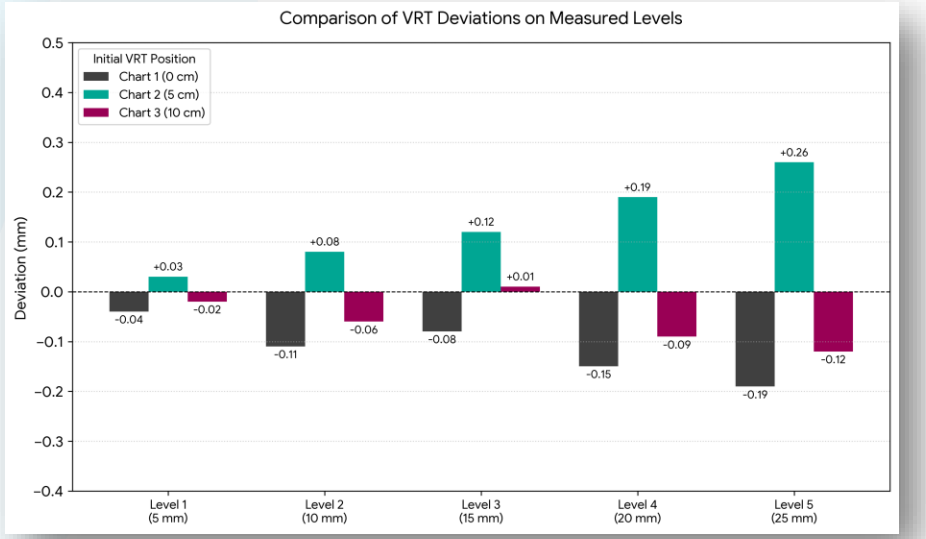
- Place leg-phantom on CT-couch, propped up on support
- Align central ball-bearing to isocentre in SUP-INF and L-R direction
- Take reference capture of phantom surface
- Make fine-tune alignment of ball-bearing to isocentre in ANT-POST direction
- Select VERT starting position (start at 0 an 10 cm above isocentre)
- Start monitoring the patch
- Move CT-coucj on vertical from 5 mm to 5 mm
- Record the data

Affix 5 ball-bearings to leg phantom: one for indicate location of iso in treatment plan and the other four to indicate laser/tattoo set-up



Vertical movement - SimRT





Performance Indicators (0 - 25 mm Range)

- **Maximum positive error**: +0.26 mm (Plateau 5, Graph 2)
- **Maximum negative error**: -0.19 mm (Plateau 5, Graph 1)
- **Maximum absolute discrepancy**: 0.26 mm

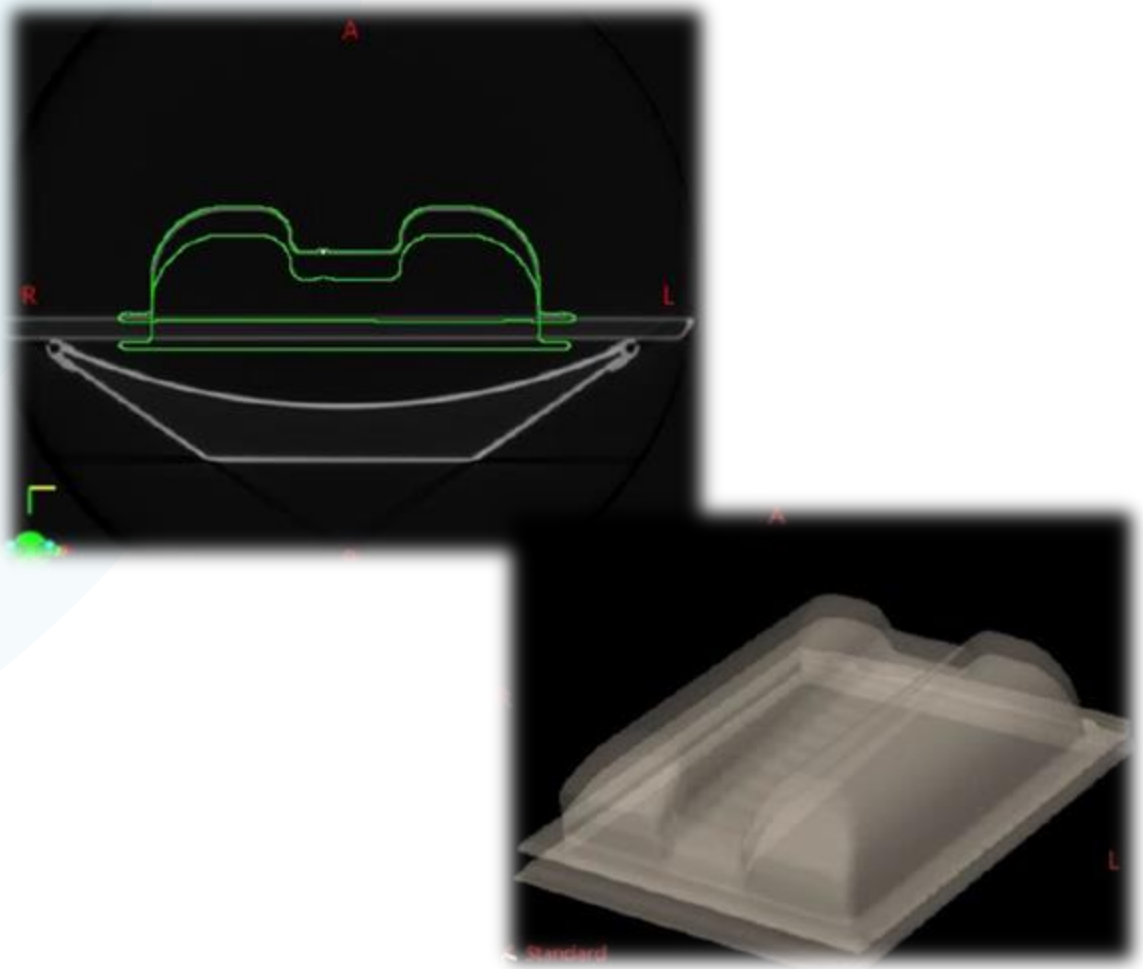
VRT Measurements and Deviations Summary

Plateau (Target)	Graph 1 (0 cm)	Deviation G1	Graph 2 (5 cm)	Deviation G2	Graph 3 (10 cm)	Deviation G3
Plateau 1 (5.00 mm)	4.96 mm	-0.04 mm	5.03 mm	+0.03 mm	4.98 mm	-0.02 mm
Plateau 2 (10.00 mm)	9.89 mm	-0.11 mm	10.08 mm	+0.08 mm	9.94 mm	-0.06 mm
Plateau 3 (15.00 mm)	14.92 mm	-0.08 mm	15.12 mm	+0.12 mm	15.01 mm	+0.01 mm
Plateau 4 (20.00 mm)	19.85 mm	-0.15 mm	20.19 mm	+0.19 mm	19.91 mm	-0.09 mm
Plateau 5 (25.00 mm)	24.81 mm	-0.19 mm	25.26 mm	+0.26 mm	24.88 mm	-0.12 mm

Vertical movement - AlignRT

Static accuracy of AlignRT:

- Acquire one image of the leg phantom (recommended low-dose CT-scan)
- Acquire second image of the leg phantom (planning image)
- In TPS:
  - On each CT-data set, create body structure
  - On the first CT-dataset, shift body-structure by 2 cm posteriorly



Vertical movement - AlignRT

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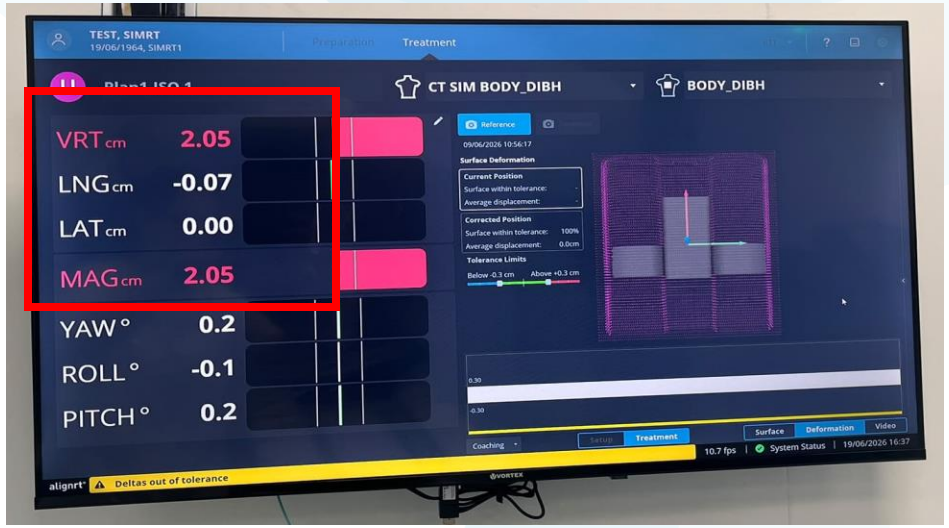
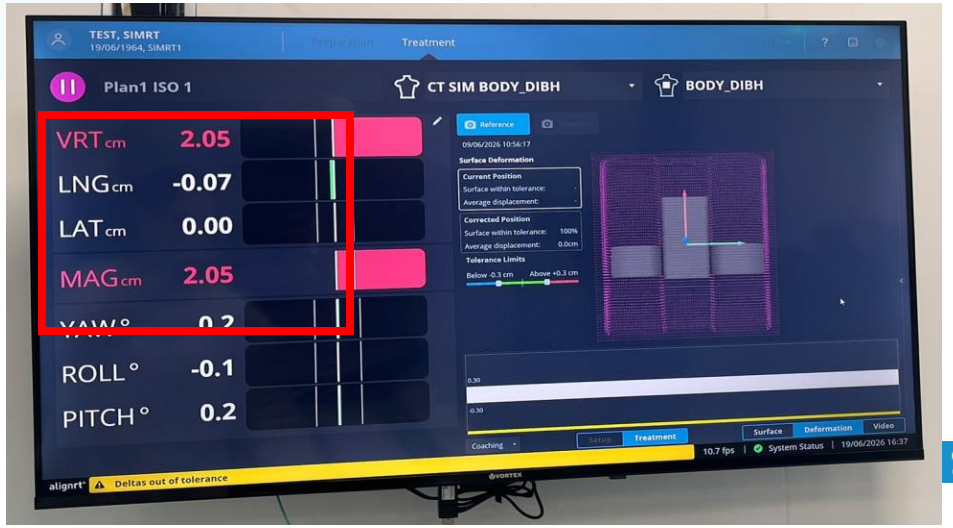
Step 1. OUT OF BORE - Align using FB structure

Step 2. OUT OF BORE - Align using BH structure



Step 3. IN BORE - translate phantom in bore and use FB structure

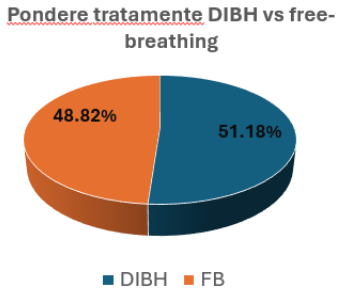
Step 4. IN BORE - monitor using BH body structure



- Used for all sites
- the beginning of the SGRT implementation without the simulation component (SIM RT).Compensate with an internal protocol
- required a learning curve for all staff

First “power point” conclusion

Statistical data on the use of AlignRT in the treatments of breast

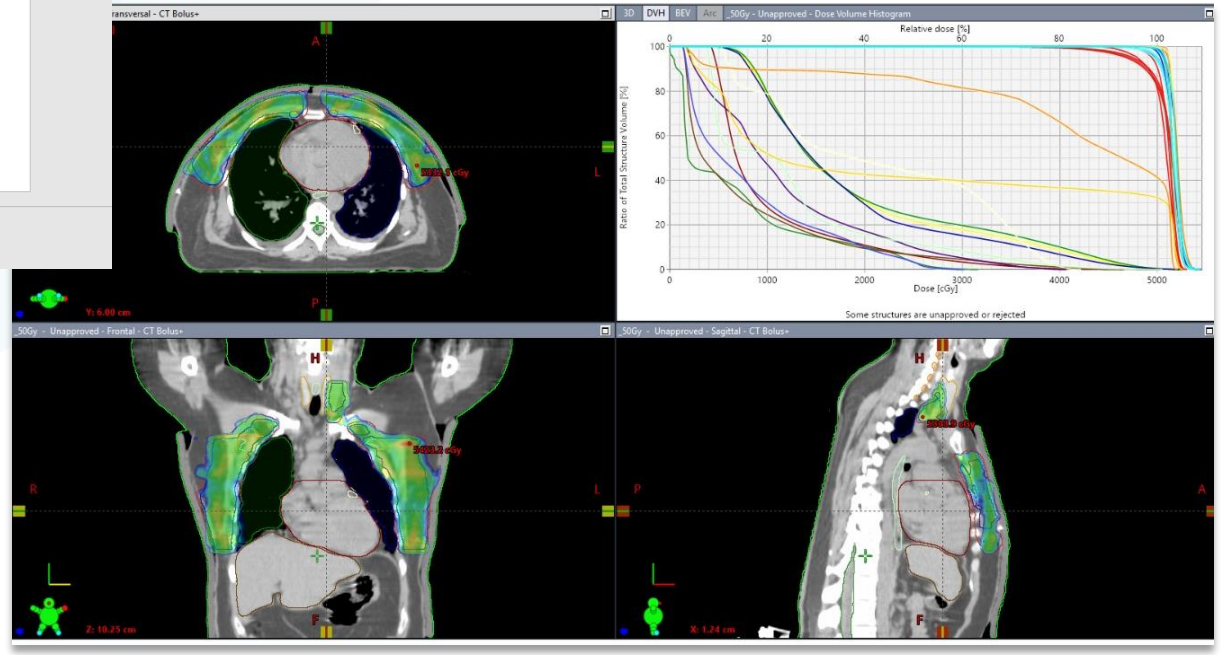


Doza medie la inima (Gy)			
San drept FB	San drept DIBH	San stang FB	San stang DIBH
3.17	2.19	6.43	4.03

Doza medie la inima (Gy) - INCEPUT implementare DIBH			
San drept FB	San drept DIBH	San stang FB	San stang DIBH
3.17	2.41	6.43	4.56

Doza medie la ini	Gy) - EXPERIENTA implem		re DIBH
San drept FB	San t DIBH	San stang FB	San g DIBH
3.17	1.96	6.43	3.04

and bilateral breast



E2E audit

succeSRS succeSBRT

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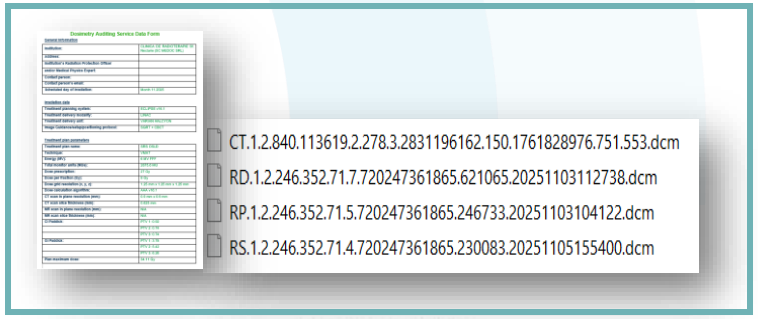
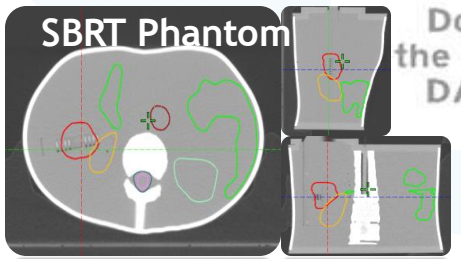




Create patient in TPS and import reference data set

Download the reference DATASET

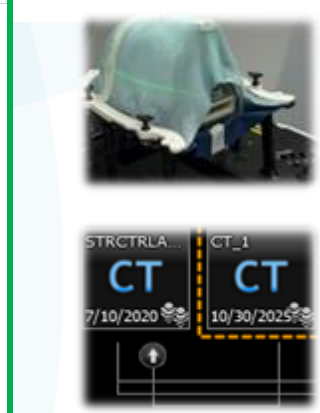
Receive Prime/SBRT phantom with the dosimeters

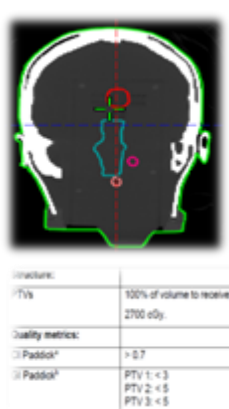
Upload the plan Data

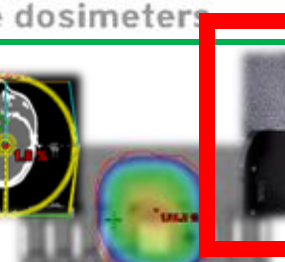
Follow the SRS/SBRT treatment steps

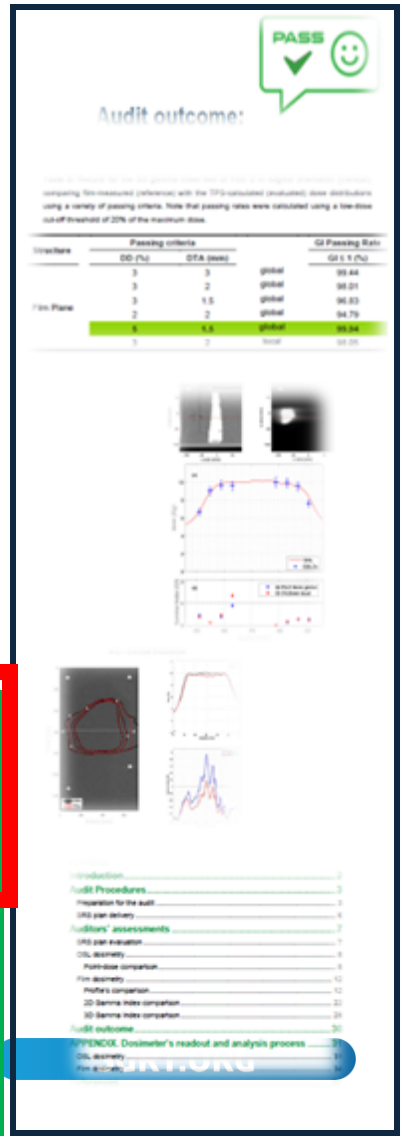
Receive Dosimetry Report

Send back the Prime/SBRT phantom with the dosimeters









E2E audit results

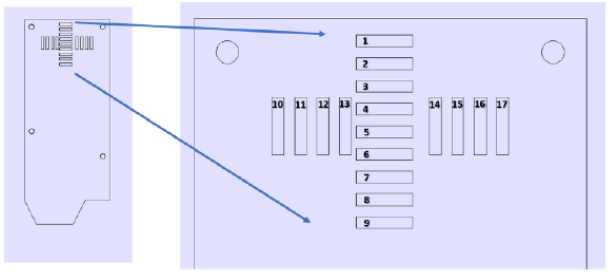
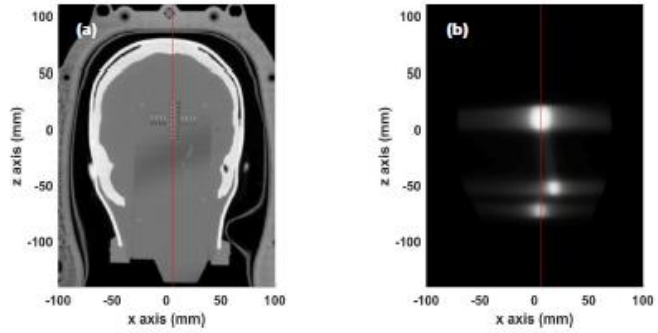


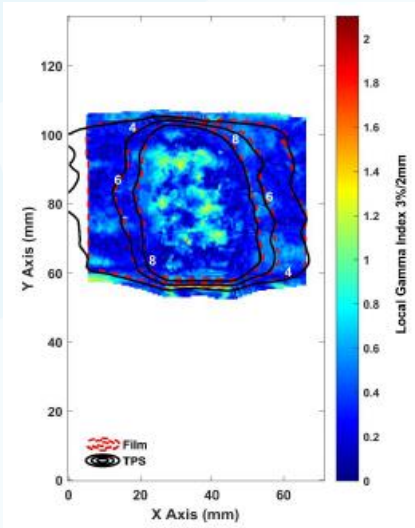
Figure 3: Schematic representation of the dosimetry cassette placed along the coronal plane through the phantom showing all OSL dosimeters.

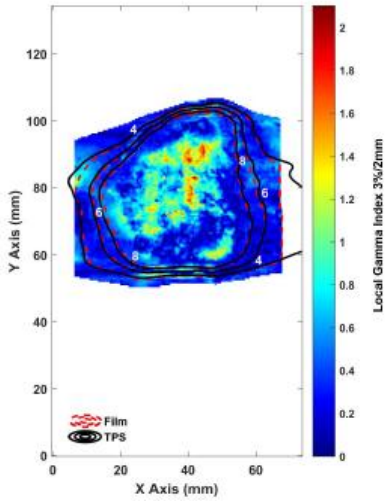
Position IDs	TPS calculated dose per fraction (Gy)	OSL measured dose (Gy)	Dose difference (%)	GI 5%/1mm Global	GI 3%/2mm Local
1	1.860	1.906	2.410	0.101	0.126
2	3.266	3.418	4.429	0.222	0.161
3	7.859	7.812	-0.604	0.104	0.098
4	10.481	10.509	0.264	0.062	0.075
5	10.615	10.731	1.084	0.241	0.226
6	10.651	10.616	-0.334	0.078	0.081
7	10.239	10.333	0.916	0.200	0.171
8	7.530	7.266	-3.627	0.201	0.108
9	1.482	1.496	0.918	0.030	0.161
10	3.596	3.636	1.110	0.090	0.111
11	4.482	4.531	1.094	0.109	0.120
12	6.346	6.428	1.285	0.103	0.078
13	9.290	9.542	2.637	0.343	0.206
14	8.740	8.709	-0.358	0.070	0.110
15	5.886	6.009	2.045	0.177	0.110
16	4.342	4.421	1.777	0.153	0.151
17	3.621	3.614	-0.203	0.016	0.063
			Fails #:	0	0
			Passing rate:	100.0%	100.0%

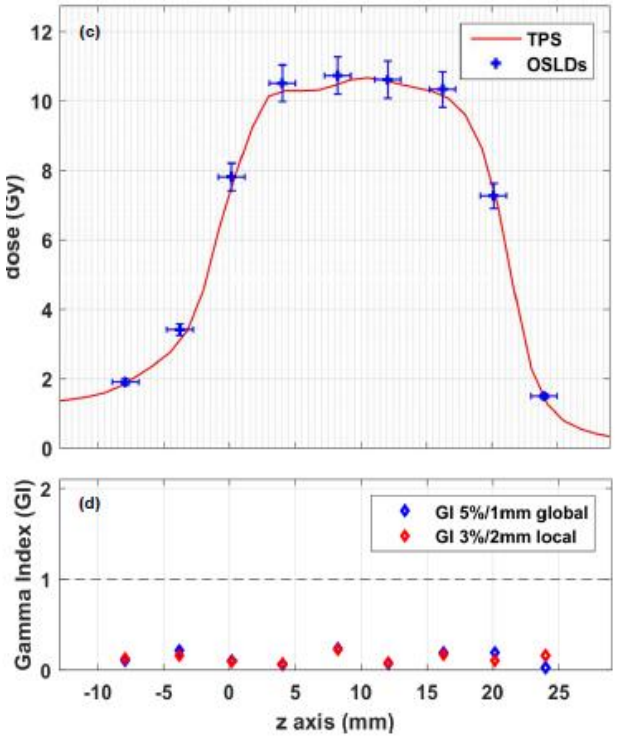
Table 5: Results for the 3D gamma index test of Film 2 in sagittal orientation (Vertical), comparing film-measured (reference) with the TPS-calculated (evaluated) dose distributions using a variety of passing criteria. Note that passing rates were calculated using a low-dose cut-off threshold of 20% of the maximum dose.

Structure	Passing criteria			GI Passing Rate
	DD (%)	DTA (mm)		GI ≤ 1 (%)
Film Plane	3	3	global	99.44
	3	2	global	98.01
	3	1.5	global	96.83
	2	2	global	94.79
	5	1.5	global	99.94
	3	2	local	98.83









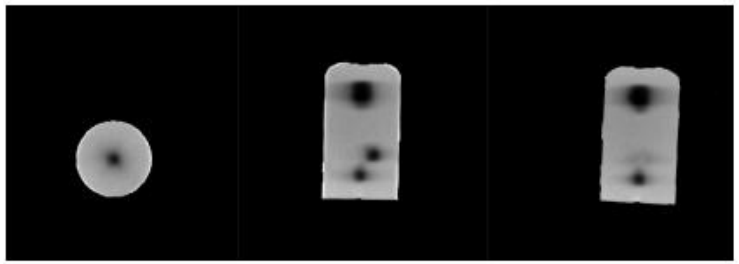
Gel Dosimetry

Table 9: Results of the calculated distances between (a) the CoM coordinates of each target and the planning isocenter and (b) the x CoM coordinates i.e., R-L direction, (c) the y CoM coordinates i.e., A-P direction, (d) the z CoM coordinates i.e., S-I direction, and (e) the total spatial offset, of the polymerized area and the planned high-dose area for the structures considered.

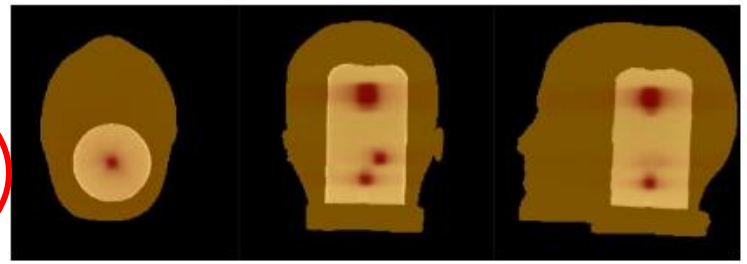
	(a) Target distance from ISO (mm)	(b) x - axis offset (mm)	(c) y - axis offset (mm)	(d) z - axis offset (mm)	(e) Total geometric offset (mm)
PTV 1	39.017	0.376 ± 0.092	0.700 ± 0.034	0.946 ± 0.207	1.235 ± 0.026
PTV 2	25.133	0.426 ± 0.099	0.529 ± 0.108	0.267 ± 0.168	0.728 ± 0.013
PTV 3	44.199	0.106 ± 0.064	0.583 ± 0.049	0.206 ± 0.134	0.627 ± 0.004

Gel relative dose 0% - RTDOSE TPS 100%

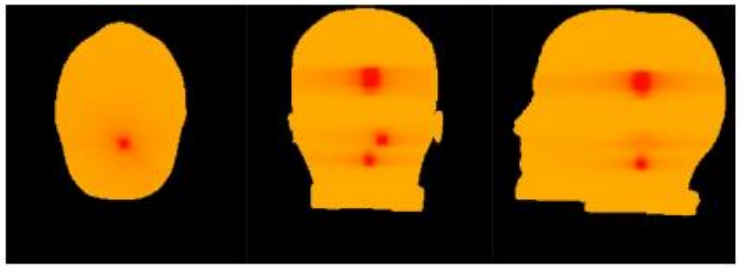
Figure 22: Illustration of the relative dose map depicted from the MRI scans of the gel blended with TPS DICOM RT data. Brightness and contrast are adjusted so that high dose areas are depicted.



Gel relative dose 100% - RTDOSE TPS 0%



Gel relative dose 50% - RTDOSE TPS 50%

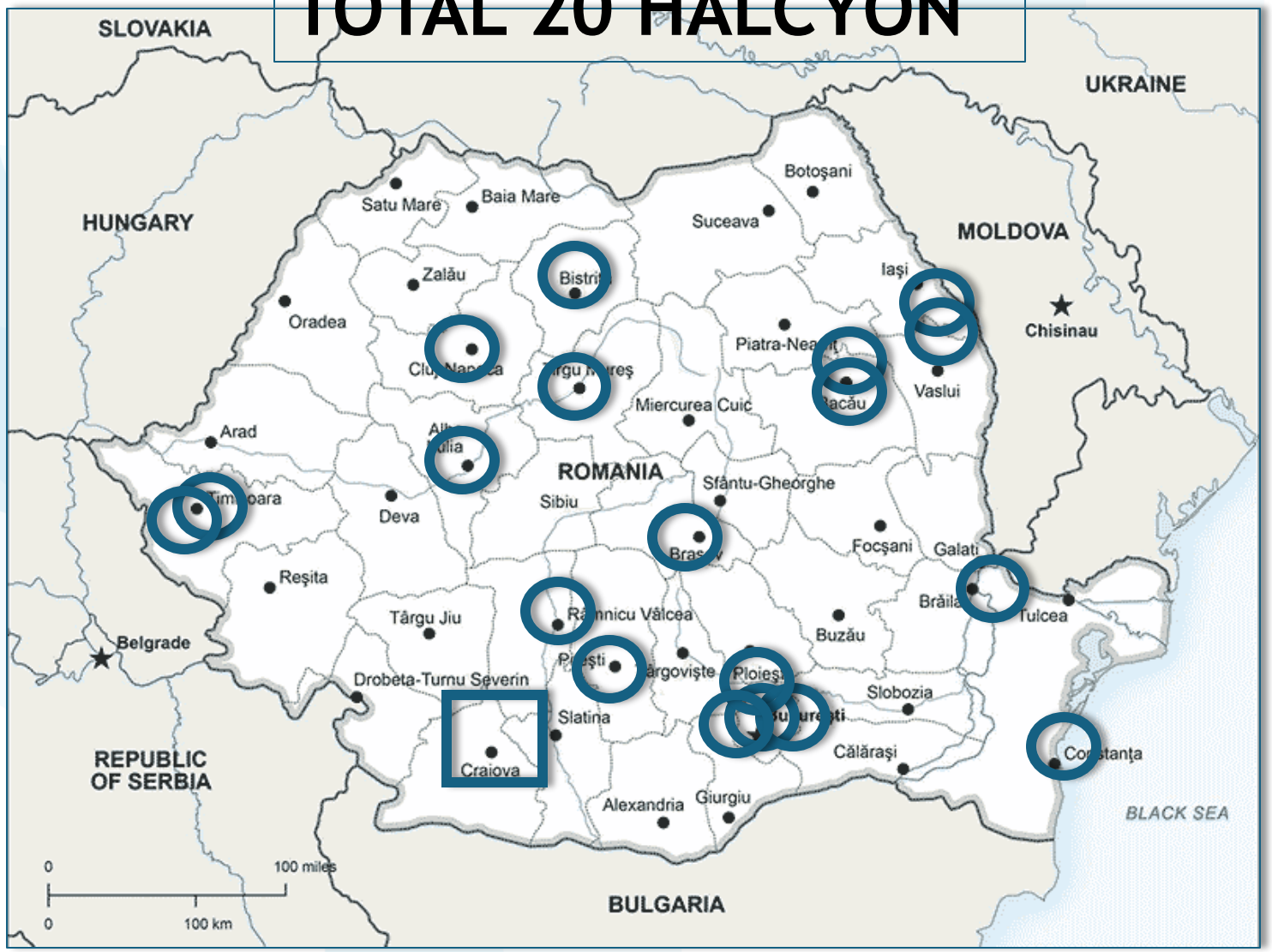


Gel relative dose 0% - RTDOSE TPS 100%

Figure 23: Illustration of the MRI (actually delivered dose) blended with TPS (calculated dose). Brightness and contrast are adjusted so that low dose areas are depicted.

To asset the total spatial offset of the planned dose distribution and the corresponding gel-measured dose distribution for each target, the geometric distance between the center of masses was calculated. Results are summarized for each coordinates x (right-left), y (anterior-posterior), z (superior-inferior), as well as for the total spatial offset.

TOTAL 20 HALCYON



End of the year 2026
~ 20 Halcyon

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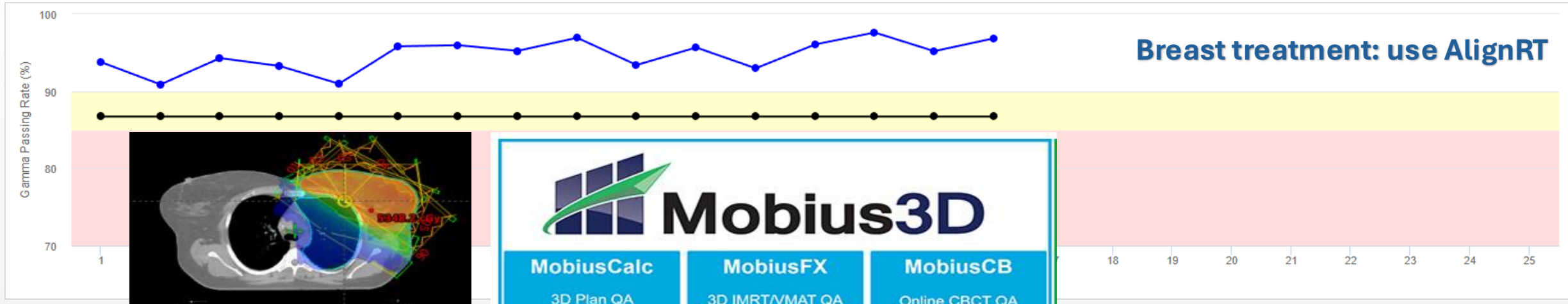
Gamma Per Fraction ▲

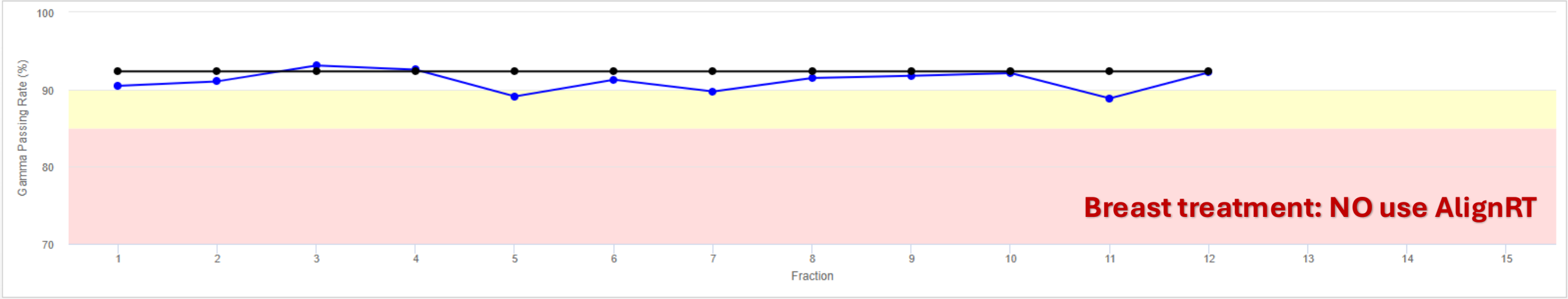


Breast treatment: use AlignRT

Mobius3D

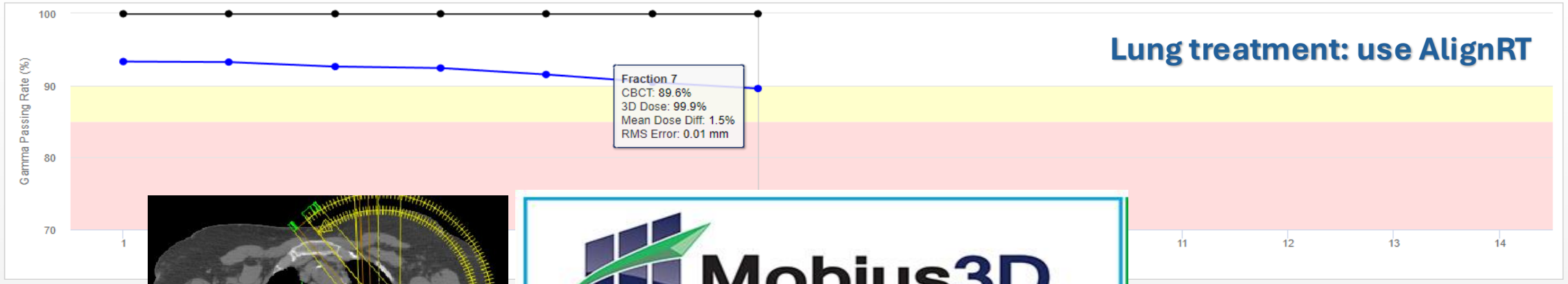
MobiusCalc	MobiusFX	MobiusCB
3D Plan QA	3D IMRT/VMAT QA 3D Daily Treatment QA	Online CBCT QA Offline CBCT Review

Gamma Per Fraction ▲

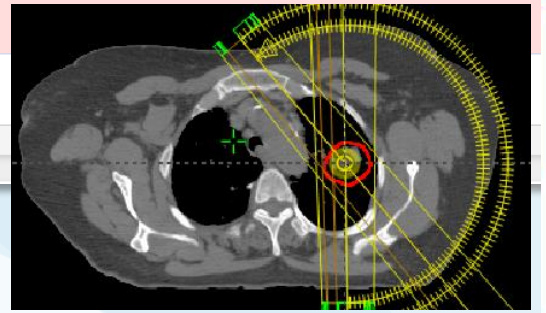


Breast treatment: NO use AlignRT

Gamma Per Fraction ▲



Lung treatment: use AlignRT



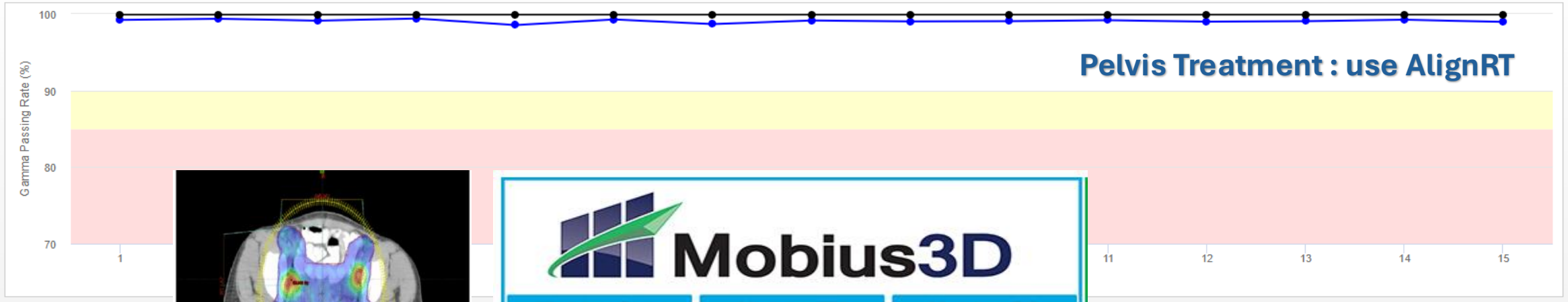
Mobius3D

MobiusCalc	MobiusFX	MobiusCB
3D Plan QA	3D IMRT/VMAT QA 3D Daily Treatment QA	Online CBCT QA Offline CBCT Review

Gamma Per Fraction ▲

Lung treatment: NO use AlignRT

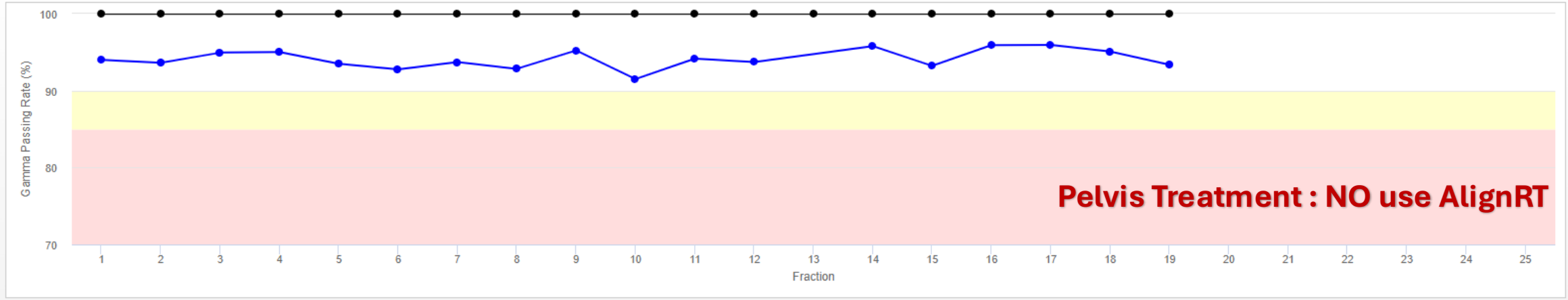
Gamma Per Fraction ▲



Mobius3D

MobiusCalc	MobiusFX	MobiusCB
3D Plan QA	3D IMRT/VMAT QA 3D Daily Treatment QA	Online CBCT QA Offline CBCT Review

Gamma Per Fraction ▲



- visible results in decreasing the time allocated to patient positioning using the "postural" option
- less number of CBCT for extremity site’s treatments
- improving the average dose to the heart for breast cancer treatments using the DIBH technique
- can achive LAD dose constrain
- increasing the time allocated to patients treated with the DIBH technique (9 minutes / patient vs 12 minutes / patient)

Take it home message !

Implementing SGRT system into the clinical practice requires not only the definition of steps in clinical workflow, but also **establishment of the comprehensive quality assurance (QA) program including commissioning, acceptance and periodic QA test to facilitate a safe, and efficient use of SGRT system** in clinical settings

Thank you for your attention!

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Q&A

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