Electronic Supplement

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	Consistent settings documented and used

		contour leads to variations in the structures	
	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

Appendix II - Example of a technical equipment selection checklist. The information should be sought from the SGRT vendor as part of the evaluation process before purchase. The checklist is not meant to be comprehensive and should be adapted to individual needs.

Option A – Equipment type: Treatment room

System/Model Full Name	
EC/FDA/TGA Registered (Year)	

Section A1 Technical Specification

A1.1 Physical Specifications

Item	**Specification**
Number of units/pods per accelerator	
Weight of one unit	
Size of one unit	
Ceiling mounting considerations	
Power specifications	

A1.2 Connectivity

Item	**Specification**
How does the system integrate with record and verify (R&V) systems? - Can patient data from the RV system be imported into the SGRT system when a patient is setup - Will the SGRT system open a patient that has been opened in the RV system - Will the SGRT system send results (which ones) to the RV system following each	

fraction or at the end of the treatment (manually/automatically)	
How does the system connect with treatment machines? Can it control the beam (on/off/both)? - Which machines can it work with (or ask specifically regarding the types of the relevant machines here)	
How are multiple SGRT systems within a department connected? Is there a common database?	
Can a patient be easily treated on one treatment machine with one SGRT system on one day and on another treatment machine with another (identical) SGRT system the next day?	
Can the SGRT system be connected to the CT?	
Can additional offline workstations review the images and statistics (PCs of ROs, physicists, chart rounds)?	

A1.3 General Imaging and Monitoring parameters

Item	**Specification**
Surface imaging principle	
Field of view	
Imaging frame rate (and its dependence on settings)	
Surface matching algorithm(s)/ approach	
Accuracy (during setup / monitoring / gating)	
How is the area / are the areas of the patient being tracked managed? Are there user selectable items?	
Dimensions monitored before / during treatment	

What is the observed surface compared to? Reference surface from CT, Reference surface obtained at some point at the system (how many can be stored)	
What report is available from a treatment? Which statistics are offered?	
Feedback to the patient (type/parameters)	
At which couch angles does the system work? Are there limitations in accuracy for some couch angles?	
What are limitations in terms of shadowing by components of the treatment system (linac head, MV / kV imaging panel, kV source)?	
Is the system performance dependent on external or patient related conditions (patient skin tone, influence of the room light)?	

A1.4 Application for breath hold techniques

Item	**Specification**
Is the system capable of DIBH monitoring?	
Additional components required?	
What are the differences in DIBH monitoring compared to other monitoring?	
What are the system gating latency specifications?	

A1.5 Application for SRS

Item	**Specification**
Is the system capable of SRS monitoring?	

Additional components required?	
What are the differences in SRS monitoring compared to other monitoring?	

A1.6 Additional Features

Item	**Specification**
Workflow features	
Linac integration	
Others	

Section A2 Installation & Commissioning

The system installation and associated infrastructure shall be a project managed by the vendor in association with the hospital's facilities management. A suitably experienced project manager shall be provided for the duration of the project and shall be available for regular scheduled project meetings with the hospital's project team. The vendor shall ensure the load-bearing and vibrational dampening capacity of the ceiling.

Installation works must not prevent nearby clinical operations from taking place and all work that may have an impact on clinical operations shall take place after hours or on weekends.

Acceptance testing and commissioning of the systems will take place with a hospital appointed medical physicist.

Item	**Specification**
Confirm acceptance of all above points or list exceptions:	
The typical duration of installation & commissioning (days)	
Can work be performed after hours and on weekends?	
Typical delivery after order placed (weeks)	
All test equipment required for acceptance testing and commissioning will be supplied (Y/N)	

Vendor description of default acceptance tests	
Justification of differences between default vendor acceptance tests and tests recommended in ACROP guideline	

Section A3 Maintenance & QA

Item	**Specification**
Provide a copy of the standard maintenance contract including offered variations or options	
Location and number of service engineers available to support SGRT systems at our facility	
Guaranteed time on site of service engineer after call logged with machine inoperable (hrs)	
Remote diagnostics (Y/N)	
Spare parts stores and approx. value of spares	
Frequency and duration of scheduled services	

Section A4 Training & Support

Item	**Specification**
Detail of applications training provided at installation (duration & number of staff) and refresher training	
List available operator training courses including location and cost. Provide staff background requirements for this course.	
Location of experienced SGRT applications specialist/trainer(s)	

Section A5 Research & Development

Item	Specification
Is a research agreement possible for further development of the system or specific applications and if so under what conditions?	
Is there other support for research activity provided by the vendor?	

Section A6 Reference Sites

Provide name and contacts of at least 2 reference sites using the same equipment being offered here:

Option B – Equipment type: simulator room

System/Model Full Name	
EC/FDA/TGA Registered (Year)	

Section B1 Technical Specification

B1.1 Physical Specifications

Item	Specification
Number of units	
Weight of one unit	
Size of one unit	
Ceiling mounting considerations	
Power specifications	

B1.2 Connectivity

Item	Specification
How does the system integrate with CT workstation? - Can patient data from CT workstation be imported into the SGRT system when a patient is setup - Will the system send results (which ones) to CT workstation and TPS or OIS following simulation (manually/automatically)?	
How does the SGRT system connect with the CT scanner? - (Specify brand)	
Is there a common database with the SGRT systems on the treatment machines?	
Can additional computers review the images and statistics (PCs of ROs, physicists, chart rounds)?	
Can the system be connected and integrated to the R&V systems?	
Can the CT SGRT system be integrated with the motion management or gating interfaces on the corresponding treatment machines?	

B1.3 General Imaging and Monitoring parameters

Item	Specification
Imaging principle	
Field of view	
Imaging frame rate (and its dependence on settings)	

Algorithm(s) for matching	
Accuracy (during setup/monitoring)	
How is the area / are the areas of the patient being tracked managed? Are there user selectable items?	
Dimensions monitored before / during simulation	
What report is available from the simulation? Which statistics are offered?	
Feedback to the patient (type/parameters)	

B1.4 Application for deep inspiration breath-hold and gating

Item	**Specification**
Is the system capable of simulations for DIBH?	
Additional components required?	
What are the differences in DIBH monitoring compared to other monitoring?	
What is the temporal accuracy?	
Is both retrospective and prospective gating available?	
Is both amplitude- and phase-based gating available?	

B1.5 Application for SRS

Item	**Specification**
Is the system capable of SRS monitoring?	

Additional components required?	
What are the differences in SRS monitoring compared to other monitoring?	

B1.6 Additional Features

Item	**Specification**
Workflow features	
MRI compatible? If so, what limitations?	
Others	

Section B2 Installation & Commissioning

The system installation and associated infrastructure shall be project managed by the vendor in association with the hospital's facilities management. A suitably experienced project manager shall be provided for the duration of the project and shall be available for regular scheduled project meetings with the hospital's project team.

The vendor shall ensure the load-bearing and vibrational dampening capacity of the ceiling.

Installation works must not prevent nearby clinical operations from taking place and all work that may have an impact on clinical operations shall take place after hours or at weekends.

Acceptance testing and commissioning of the systems will take place with a hospital appointed medical physicist.

Item	**Specification**
Confirm acceptance of all above points or list exceptions:	
The typical duration of installation & commissioning (days)	
Can work be performed after hours and on weekends?	
Typical delivery after order placed (weeks)	
All test equipment required for acceptance testing and commissioning will be supplied (Y/N)	

Vendor description of default acceptance tests	
Justification of differences between default vendor acceptance tests and tests recommended in ACROP guideline	

Section B3 Maintenance & QA

Item	**Specification**
Provide a copy of the standard maintenance contract including offered variations or options	
Location and number of service engineers available to support SGRT systems at our facility	
Guaranteed time on site of service engineer after call logged with machine inoperable (hrs)	
Remote diagnostics (Y/N)	
Spare parts stores and approx. value of spares	
Frequency and duration of scheduled services	

Section B4 Training & Support

Item	**Specification**
Detail of applications training provided at installation (duration & number of staff)	
List available operator training courses including location and cost. Provide staff background requirements for this course.	
Location of experienced SGRT applications specialist/trainer(s)	

Section B5 Research & Development

Item	Specification
Is a research agreement possible for further development of the system or specific applications (like DIBH) and if so under what conditions?	
Is there other support for research activity provided by the vendor?	

Section B6 Reference Sites

Provide name and contacts of at least 2 reference sites using the same equipment being offered here:

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.
A3	Rotational shifts	**Agreement between introduced and detected rotation in each direction** An appropriate phantom should be positioned on the couch at known angles relative to 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 by starting from the reference position and introducing rotational changes. For rotation, the couch can be rotated. For roll and pitch, the couch can be used, if capable. Otherwise, a rigid sheet can be placed under the phantom (e.g. 1 cm solid water) to introduce roll or pitch. The angle can be measured with a digital level and compared to the one detected by the SGRT system.
A4	Impact of camera occlusion	**Introduced shifts when one or more camera pods are blocked** (For multi-camera systems only) This applies to -multi-camera systems only. Since camera pod occlusion can be avoided in the patient setup phase, this test relates to patient monitoring during treatment.

		An appropriate phantom should be positioned on the couch so that the isocentre is inside the phantom. For the first test, the phantom should be aligned to its reference image, or a new reference image should be obtained, depending on the specifics of the SGRT system. With the SGRT system in monitoring mode, the gantry or other obstructions are placed in the path of one or more camera pods with the respective time points noted. All clinically relevant scenarios should be covered. Introduced erroneous translational and rotational shifts when one or more camera pods are blocked should be recorded. For commissioning, the test should be repeated with the phantom offset from the expected position, as deviations from an expected zero offset might be handled differently than deviations from an expected actual offset. As the expected effect has been shown to depend on the field of view / ROI /type-of-reference, the test should be performed with two ROIs bracketing the sizes of the clinically expected ROIs. Any possible impact of camera occlusion has to be adopted in the clinical workflow (e.g. reduce the percentage of blocked views through treatment planning or adapt the ROI accordingly). The impact of the blocking of 2 camera pods should be assessed and the workflow should be adapted accordingly.
A5	Couch rotation	**Agreement between couch angle as per machine and per SGRT system** <u>Integration test:</u> 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). <u>Basic</u>: 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. <u>Radiographic</u>: 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.
A6	Setup/loading position	**Confirm the system calibration at a non-isocentric position** Only for treatment systems where the patient position is verified at two distinctive positions (i.e. CT, closed-bore linacs, some particle therapy facilities) Confirm the system calibration at the patient setup/loading position.

A7	Multiple isocentres	**Verify if the system can handle plans with multiple isocentres** A treatment plan with multiple isocentres is generated in the TPS (if possible) and transferred to the SGRT system. The plan is loaded consecutively in the SGRT and R&V system. The correct handling of the different isocentres and reference surfaces is checked. If the TPS has the option to create different planning cases, the handling of different cases should be also verified.
E1	End-to-end positioning test	**Verify the entire workflow** CT scan, plan and set up a phantom confirming correct position at treatment machine (assessed with the same IGRT method used at treatment) <u>Basic</u>: CT scan, plan and set up a phantom confirming correct position at the treatment machine. <u>Multiple Scenarios</u>: CT scan, plan and set up a phantom confirming correct position at the treatment machine, in all the different applications of the SGRT-system (setup, DIBH, DEBH, FB-Gating,) <u>SGRT at CT:</u> 4DCT test acquisition including examination of 4DCT quality
D1	Beam hold performance	**Beam hold performance** <u>Functionality:</u> Interface w/3rd party systems. Time delay when beam hold is triggered (visually). Check the configuration parameters: delay time, limits/tolerance, scale <u>Dosimetric:</u> Dosimetric integrity (the total dose is the same for interrupted treatments as for uninterrupted ones) To test if the beam hold feature has an impact on the quality of the dose distribution. Clinical beam delivered with interruptions and the dose distribution compared with the static one via gamma analysis or a gated delivery point dose compared to a corresponding static delivery point dose. *If beam hold function is available. The size of the gating window should be clinically adapted to the characteristics of the gated beam delivery: If high dose differences between gated and static delivery are detected, the gating window has to be increased to a level where this test passes (2). Additionally, the detector should be static for this test to eliminate any possible impact of the phantom to the dose delivery, although the test should match the clinical application, which might include dynamic detectors. The impact of factors like gating window size can affect the test setup when dynamic phantoms are being used. The ability to switch off the beam once the tolerance is exceeded can be tested with a simple motion phantom (3).
D2	Tracking performance	**The ability of the system to react to translations and/or rotations of a moving object** (Accurate representation of applied translations and rotations) An appropriate phantom is positioned on the couch at its correct isocentre position (a new reference image can be taken). If a motion platform is available, that would be preferred, but it is not necessary. This test should be possible without beam on. Sets of measurements should be done for a zero-couch angle, as well as for non-zero couch angles if they are clinically used. It is recommended to use the largest couch angle and an intermediate angle and to test both directions of couch rotation. <u>Translations:</u> Agreement between introduced and detected shifts in each direction during tracking (include non-zero couch angles, if clinically used) Translations are introduced by moving the couch and comparing the applied move with the displaced value indicated by the SGRT system. If the couch motion is not accurate due to

		age and/or model of the couch, one can use a ruler and the in-room lasers to improve accuracy. <u>Rotations:</u> Agreement between introduced and detected rotation in each direction during tracking (include non-zero couch angles, if clinically used) For rotation, the couch can be rotated. For roll and pitch, the couch can be used, if capable. Otherwise, a rigid sheet can be placed under the phantom (e.g. 1 cm solid water) to introduce roll or pitch. The angle can be measured with a digital level and compared to the one detected by the SGRT system. <u>Couch motion:</u> Helical-treatment Machines: helical treatments- Static object and moving object. For different couch speeds. Impact of couch motion (translation) on the reported position of a stationary object <u>Free Breathing-Performance:</u> Measure the lag time using designated phantoms. Lag time or latency can either be evaluated using the beam-on current voltage on the linac console (if possible). As an alternative, dedicated phantoms where the dose can be evaluated over time or using fluoroscopic film measurements can be used for this test. Beam-on time can sometimes be tuned, but this will result in a lower electron gun lifetime. The beam-off lag time or latency has a higher impact on correct dose application. Always be aware of possible beam-on and beam-off latencies and ensure that the latencies of the combination of the linac and the SGRT system comply with the treatment intent.
D3	Respiratory trace	**Detectability of amplitude, frequency, shape variations** Place a motion phantom with a suitable surface detectable by the SGRT system and able to perform a clinically meaningful motion of known amplitude, frequency and shape on the treatment couch near the isocentre. Confirm that the SGRT correctly identifies the parameters of the motion. Repeat the test at different locations on the couch or with the couch moved, depending on the system used, covering the area in which motion needs to be assessed clinically. In the simplest form, frequency and motion shape could be confirmed visually. Amplitude should be available in the SGRT system. Alternatively, the recorded motion traces could be exported for comparison.
D4	Trigger performance	**Acquisition of a gated capture** Using a motion platform with a vertical motion element for triggering of the SGRT system and an internal CT visible motion element in a phantom (PTV), set the motion parameters for amplitude and period to clinically meaningful numbers with a sinusoidal or similar pattern. Obtain a 4DCT of the phantom (with the motion engaged) with the SGRT system triggering the CT. Using the measurement tools of the CT scanner (or of your TPS), quantify the relative motion of the PTV for each phase, confirm that it follows the expected (sinusoidal) pattern and that it is in phase (e.g., bin 1 corresponds to highest or lowest position, depending on the settings).
D5	Frame-Rate	**Frame-rate impact** Verify how much the frame-rate changes with different system settings and with different ROI dimensions, as these can alter the demand on available system processing power. Demonstrate that the frame rate measured matches the system description. This depends on many factors, such as acquisition protocol, ROI extension, deformable registration method, etc. For smaller ROIs monitored, the frame rate increases while the frame rate can decrease significantly for larger ROIs. The frame rate can also be dependent on system upgrades or system/PC components.

		In the acceptance test, the vendor specifications should be confirmed to be in the range specified by the vendors. During commissioning, the frame rate has to match all clinically used scenarios and setups. If the accuracy of SGRT tracking has to be high (for example for SRS treatments), the frame rate should not be a limiting factor. Some indicative values: SRS-accuracy (small ROI): approx. 20-30 fps or in datapoints/sec DIBH (medium ROI): approx. 10-25 fps Fast-Gating (small ROI): approx. 20-35 fps Setup abdomen/chest/pelvis (large ROI): 10-15 fps
P1	Thermal Drift	**Impact of temperature on the camera performance** Check camera drift after start-up and after reasonable, clinically representative breaks in a clinical mode by placing a phantom at the isocentre of the SGRT system and observing the position readout over time. Some systems allow exporting trend data, which would be helpful in this case. The FOV should be reasonable, and the isocentre should be inside the phantom. For acceptance go to standby for 20 min and then measure for 20 min. For commissioning, starting from a cold SGRT system (off overnight) the drift in the SGRT-derived phantom position is monitored for 60 min or longer if needed to reach stability. The test is repeated from standby and after reasonable breaks, applicable to the clinical workflow (e.g. 5 min between patients, and 30 min) to gain an understanding of the system drift under these conditions. Here the test duration can be shortened if stability is reached earlier. Based on this, the clinical usage strategy is defined. It should be designed to ensure that any drift stays within the recommended tolerances for clinical use of the system. If needed, minimum re-warmup requirements can be included prior to any critical clinical use, such as tracking of SRS treatments. Basis for defining the strategy is the overall drift of the system as found in the measurements from a cold system state. More details can be found in Lehmann et al. (4). For ongoing quality assurance, the camera drift is measured after start-up and after a reasonable break (>30 min) for 30 min in a clinical mode. Results are compared to baseline. Following the commissioning results and vendor recommendations, the SGRT calibration procedure should always be performed in a pre-defined state (warmed-up or cold).
P2	Room-light impact	**Influence of the ambient light level on the system accuracy** Place an appropriate anthropomorphic phantom into the field of the SGRT system (around isocentre) and use a typical ROI setting. Start with the phantom aligned to the reference (e.g. by taking a new reference) and observe changes to the reported position for different ambient room light settings, including a typical room light setting during patient setup, a typical room light setting during treatment, all lights on and all lights off. Next, move the phantom by clinically reasonable distances (e.g. 5 mm in each direction) and again observe the reported shifts for the different lighting settings. Repeat the procedure with any additional clinically used lighting settings and with maximum room light intensity. Investigate the room light effects and decide for room light settings for setup and treatment that are within the tolerance stated.
P3	Field-of-view	<u>Basic:</u> Confirm that the field-of-view is within the specifications, covering a large enough volume around the isocentre for each clinically used setup, and symmetric around the isocentre. Consider possible camera pod blocking. The field-of-view in closed-bore linacs might be reduced due to camera pod obstruction. <u>Advanced:</u> Visually observe the FOV in all directions in the whole treatment volume of interest. Look for coverage as well as for any holes (gaps in surface signal due to occlusion, reflectance or signal resolution/saturation). Perform this test also with one or more camera pods blocked.

P4	Quality of acquired image	Check that a SGRT capture has enough information The image should be smooth, not containing holes or discontinuities, especially near the isocentre.
P5	Integration	**System interface with all peripheral systems** (e.g. R&V system, delivery system, TPS, CT, DICOM-server) Patient and Plan Identification - Name, position (head-first, feet-first, supine, prone), Plan correctly identified Coordinates-system - Confirm the axis of the OIS/delivery system/SGRT To check correct communication with all the peripheric systems, import suitable patient data sets into the SGRT system and confirm the information and orientation. This should include all clinically used orientations. Practically this can be done by CT simulating a phantom in the required orientations (HFS, HFP, FFS, FFP) and exporting the data sets to planning and then to the SGRT system, as well as the IOS and confirming that the orientation is correct in each system. At the same time the correct handling of patient name, plan name and angles of beams can be verified. It should be noted that some SGRT systems only support selected coordinate systems (e.g. IEC 1217), in which case procedures need to be implemented to accommodate this in the workflow.
P6	Patient Interface	**Visual or audio interface to the patient** In treatment mode, ensure the patient feedback device is working and the connection to the SGRT system is operational. Start the monitoring of a moving phantom and ensure the phantom's breathing trace is displayed on the screen of the interface for the patient.
P7	Registration-matrix Quality	**Deformable registration quality** This test is not part of regular commissioning and QA. It could be seen as an advanced test to assess system capabilities. Simplified procedure from Meyer et al. (5): - scan the phantom in CT and generate a DICOM RTstruct body surface - determine the rigid transformations and rotations first - introduce some realistic software-based deformations to the body structure from the TPS (e.g. changing the outer contour structure on certain areas of the patient surface)) and report whether the SGRT software is able to match the new deformed structure. Other methods explored in this area include Pallotta et al. (6).
S1	Interlocks	**Existence and performance** Confirm that all available interlocks are operating correctly and as intended. Verify that the beam is held in case of system breakdown or loss of communication.
S2	Data import / export	DICOM integration: Check if data import and export work correctly and if all DICOM specifications, such as coordinate system, gantry and couch angles, patient ID, patient name, patient orientation, etc., are transferred and interpreted correctly by the SGRT system.
S3	Database backup & security	Network integration, backups, and data safety Perform regular backup of the database.
S4	System configuration	User Rights: Different users should be assigned different rights according to their responsibilities. Confirm that the user rights have not been changed since commissioning. Consider password changes. Pre-sets: Check that all Pre-sets are still set as intended. Camera Settings: Confirm that the (global) camera settings have not been changed. System Integrity and Performance Security: Confirm the system correctly detects if every part of it is working properly. Some features of the system could be malfunctioning, causing no obvious effect on the functionality of the system but having an effect on the quality of the images acquired. The system should provide an online check of every part of it.

S5	Mechanical Integrity	Confirm integrity/Collisions Verify that no element can collide with the camera pods Check for visible damage of the camera pods (e.g. originating from bumping them)
R1	Export patient- & QA- reports	Export of the summary of treatment/QA in a legible format. Optional export to an OIS.
R2	User manuals	Available and written in the language of the users of the system at the specific location, unless local regulations allow otherwise.
R3	QA-Documentation	Confirm that the next lower QA has been performed over the most recent period and that there have not been any unresolved problems.
S7	Camera Settings	Confirm that the (global) camera settings have not been changed by comparing the current settings with a saved copy of the original settings.
X1	Extension of the FOV	Extension of the FOV. If used for total body irradiation (TBI) or craniospinal Irradiation (CSI) deliveries a FOV larger than a standard installation is required (see test P3). Depending on the irradiation technique, confirm if the FOV at a different source-to-surface distance (SSD) is adequate.

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

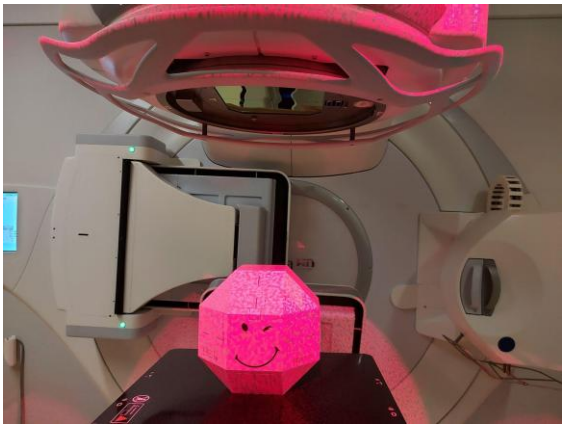
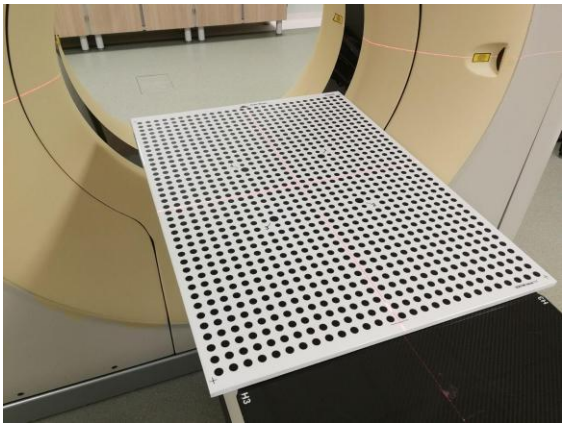
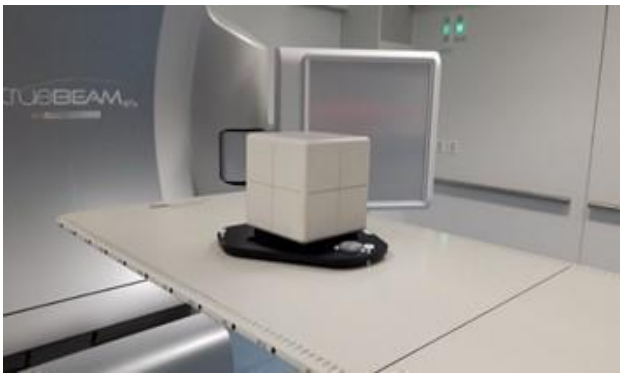
A. Phantom Requirements*

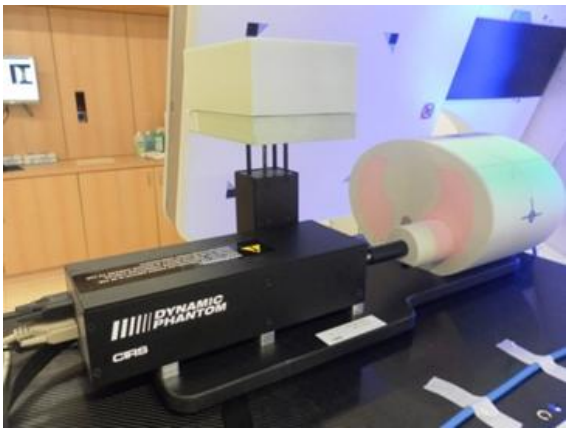
*Depending on the performed test the set of important parameters affects the phantom selection

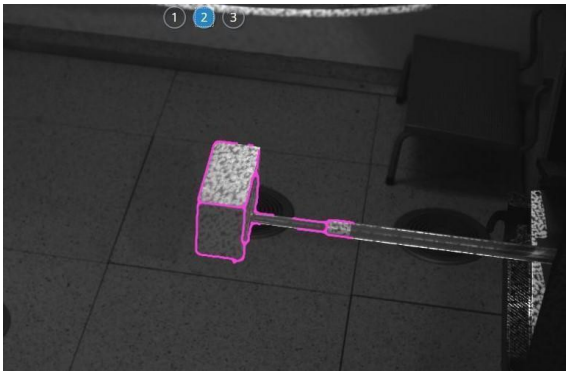
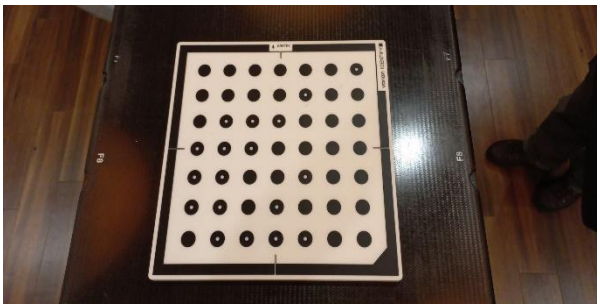
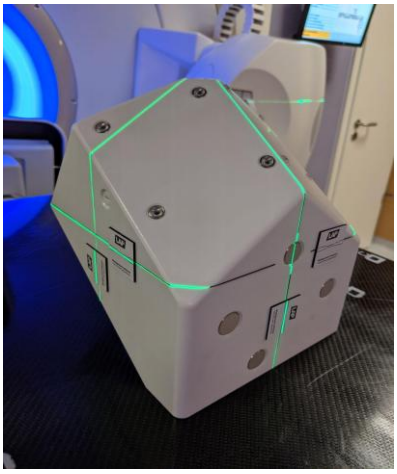
Parameter	Description of ideal characteristics
Surface colour/texture	No reflecting effect, specific landmarks, uniform surface colour, different skin colour might also be available
Dosimetry	Possibility to use ionization chambers or film
Dynamic	Simulate a regular and irregular breathing signal (accuracy 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

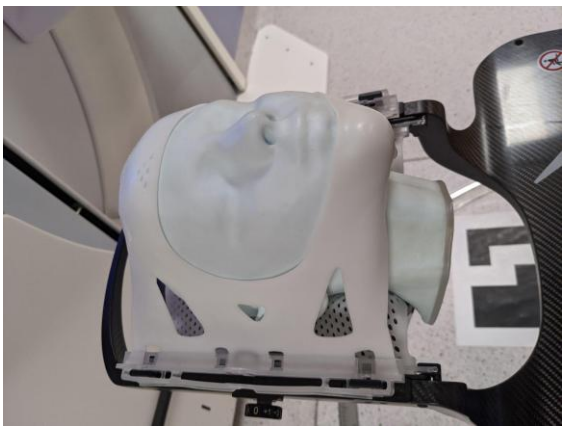
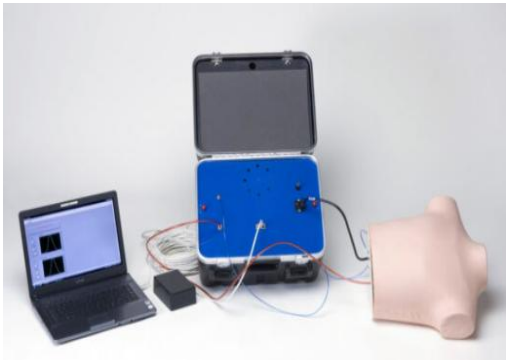
B. Commercially Available (Examples)

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.

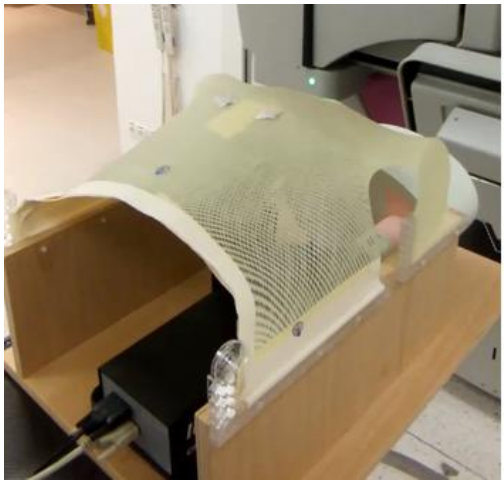
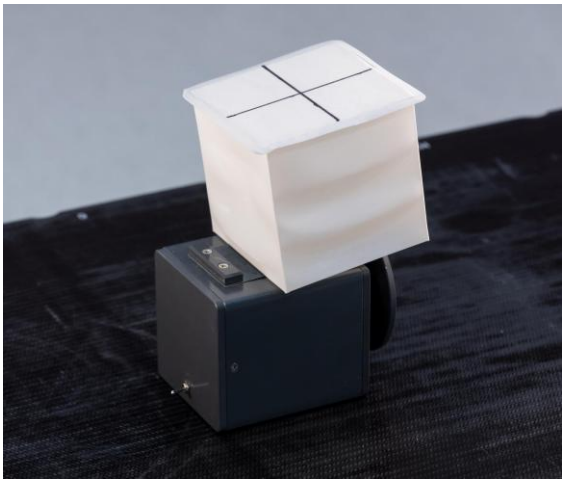
End-to-end testing -PTW Ruby (PTW Freiburg, Germany https://www.ptwdosimetry.com/)		A3, A5, A7E1	Multipurpose dosimetry phantom compatible with SGRT systems
Daily QA and Laser-Calibration (Treatment room and CT) VisionRT, London, UK https://www.visionrt.com/		A1	The centre of the plate is positioned at the isocentre of the treatment or CT room by using the X-ray imaging system (kV or MV). The four larger dots are used to triangulate the optical isocentre. If the position of the optical isocentre is out of threshold a new isocentre calibration is performed by the user with the same plate. The smaller dots are used to optimize the contrast of each camera pod. The user has to verify that, with the chosen contrast, every dot is visible by every camera.
VisionRT MV-Calibration (SRS-specific) VisionRT, London, UK https://www.visionrt.com/		A1	Cube with internal spherical markers is placed at isocentre. Using EPID images from 4 different angles calibration to the MV isocentre is performed.

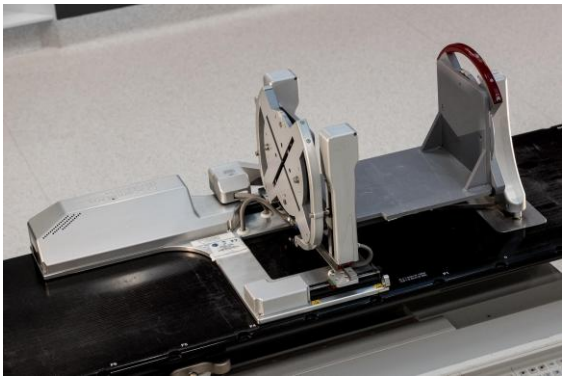
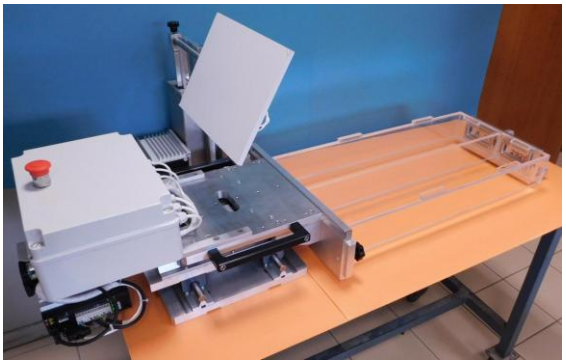
C-rad daily QA C-RAD, Uppsala, Sweden https://c-rad.com/		A1, P4	Three identical spheres in fixed arrangement. Checks all three cameras in one image acquisition.
C-RAD breathing simulator box C-RAD, Uppsala, Sweden https://c-rad.com/		E1, D1-4	Motorized breathing simulation box with a realistic breathing pattern
CIRS dynamic platform vendor, location, CIRS, Norfolk, USA (https://www.cirsinc.com/		D1-4	CIRS 4D (with in-house built platform)) Dynamic phantom with lung inserts and anthropomorphic lung, tissue, and spine structures. Multiple breathing curves can be demonstrated, the secondary platform might be used as a diaphragm or to simulate the patient surface
QUASAR^{tm} Penta-Guide phantom ModusQA, London, Ontario, Canada https://modusqa.com/		A1, A2, A5, E1	Phantom with internal structures which can be used for CT-CBCT registration

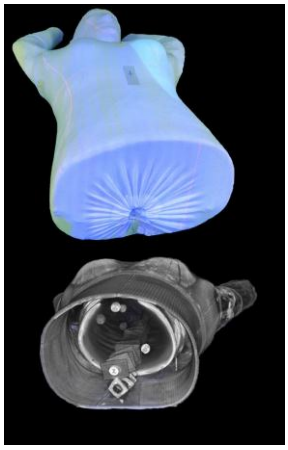
Position accuracy (3DOF) Elekta AB, Stockholm, Sweden https://www.elekta.com/			Ball bearing Phantom (Elekta) with an adapted cube phantom (in-house)
SGRT camera calibration tool Varian Medical Systems, Palo Alto, USA https://www.varian.com/		A1	DailyQA phantom for IDENTIFY
Styrofoam head phantom Varian Medical Systems, Palo Alto, USA(Varian) https://www.varian.com/		A2, A3	Styrofoam head
Brainlab Daily QA Brainlab AG, Munich, Germany https://www.brainlab.com/		A1, P4	ExacTrac Dynamic (Brainlab AG, Germany) daily QA phantom with several built-in ball bearings used for a consistency check between surface/thermal camera and X-ray system

Brainlab anthropomorphic SRS phantom Brainlab AG, Munich, Germany https://www.brainlab.com/		A1, A2, A5, E1	Anthropomorphic phantom with 3 ball bearings to calibrate and check the radiation isocentre according to ExacTrac Dynamic.
RTSafe surface/thermal phantom RTSafe, Athens, Greece https://rt-safe.com/		A1, A2, A5, E1	Anthropomorphic phantom with 3 ball bearings to calibrate and check the radiation isocentre. The phantom can be filled with warm water up to 50°C and the surface is designed specifically for visualization of SGRT systems.
RSD Phantoms RS1500 Breathing Phantom https://rsdphantoms.com/product/dynamic-breathing-phantom/	 Image courtesy: Radiology Support devices Inc., Long Beach, CA, USA	D1-4	Dynamic phantom with lung inserts and anthropomorphic lungs, ribcage/chest-wall bone, skin and sub-dermis. Different breathing curves can be simulated with lung tumour and surface motion.
C. In-house built Phantoms			
Name of the phantom	Illustration	Used in test	Main characteristics

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

Breathing motion phantom extension		D1, D3, S1	Thermoplastic mask material shaped to a thorax with movements using the CIRS 4D platform
Daily triggering phantom addon			3D printed hollow cube structure to use with the standard Varian motion phantom, thereby making it suitable for SGRT QA
End-to-end test phantom skin with breast feature			Thermoplastic attachment made for commercial phantom to add surface features in the sup-inf direction. The resulting phantom can be used for end-to-end tests of breast treatment workflow with SGRT

Platform attachment for the HexaMotion platform.			With a platform attachment the HexaMotion platform can be used to precisely move other phantoms than the Delta4 that it is designed for.
Addition of markers for off-centre location			With markings for an off-centre location (in AP and LR→ white label tape) and using a sheet of known thickness (e.g. 1 cm) - not shown here - this vendor supplied phantom can be used to quickly verify shifts in all three directions.
Moving phantom for dosimetric verification with the use of array of ionization chambers		E1, D1, D2, D3	The phantom can move an array of ionization chambers. It can be moved in longitudinal and lateral direction with respect to the phantom axis. It also includes a surrogate motion for the tracking with the SGRT system. This phantom was designed for particle therapy applications and can be used for dosimetric verifications (e.g. end to end tests)

Phantom Mary: for deformable image registration algorithm validation		P7	anthropomorphic phantom for deformable Image Registration algorithm commissioning. (5)

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