AN MRI QUALITY ASSURANCE FRAMEWORK TO MINIMIZE LOCALIZATION ERROR IN STEREOTACTIC RADIOSURGERY

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Goals For MRI QA

1. Minimize the contribution of MRI distortion to localization error in SRS treatments.
2. Identify scanners that are not operating optimally and may require recalibration or may not be suitable for SRS use.
3. Detect acute errors in MR images that may affect SRS treatments.

Framework Overview

A four-component QA process is used to achieve these three goals. GRID[3D] phantom scans provide quantitative measurements of geometric distortion, ensuring that each scanner is operating at the highest achievable level of performance. By establishing challenging but achievable distortion thresholds, we maintain consistent image quality across the fleet. These measurements also identify scanners with more distortion, allowing them to be removed from SRS use when necessary, supporting Goal 2.

The remaining components focus on preventing acute imaging errors. The MRI console poster reinforces key acquisition requirements for SRS, the protocol monitoring dashboard verifies that each scan adheres to the approved imaging parameters, and the daily scanner status email communicates scanner eligibility to the clinical team.

Together, these components ensure consistent image quality, identify underperforming systems, and prevent errors that could impact SRS treatments.

Affiliations

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4 Components of SRS MRI Quality Assurance

Component 1: Grid Phantom Scans

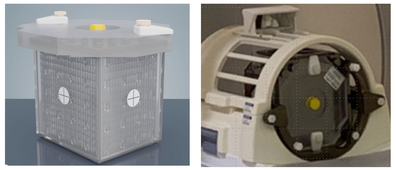


Figure: Modus QUASAR GRID 3D phantom (left) and phantom in coil ready to scan (right).

Modus QUASAR GRID 3D phantom scans are performed annually, and after

- Software upgrades
- Gradient calibration
- Gradient coil upgrades
- Any other changes that might affect distortion

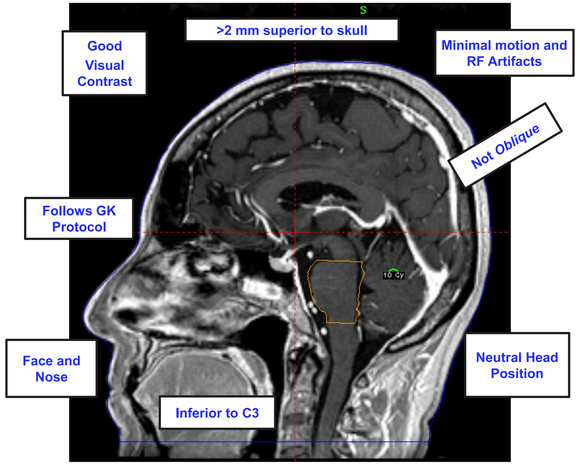
In total, approximately 80 scans are performed per year.

Geometric distortion is quantified by comparing measured grid intersection positions to their nominal locations. Tolerance thresholds were established based on the minimum localization error achievable in practice. Frameless imaging uses stricter criteria, while framed scans allow slightly relaxed thresholds due to additional distortion from the stereotactic frame. Because even small positional errors matter in SRS, thresholds are kept as tight as reasonably achievable.

Table: Localization error thresholds for GRID[3D] phantom scans

	Frameless	Framed
Mean (mm)	0.6	0.75
Maximum (mm)	1.2	1.8
90% Error (mm)	0.8	1.2
95% Less Than (mm)	0.8	1.4

Component 2: Poster at MRI Console



A reference poster is displayed at MRI consoles used for SRS to reinforce key image quality requirements. It highlights acquisition features critical for stereotactic radiosurgery that may differ from standard diagnostic imaging priorities.

Component 3: Protocol Monitoring Dashboard

Strict adherence to the MRI protocol is critical for SRS. Changes to parameters such as bandwidth or distortion correction can significantly degrade geometric accuracy, even when differences are not visually apparent.

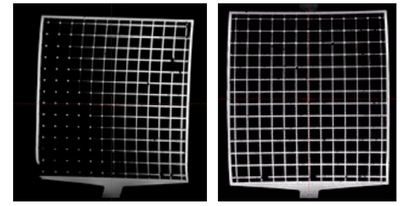


Figure: Phantom scan with distortion correction turned on, left, and turned off, right.

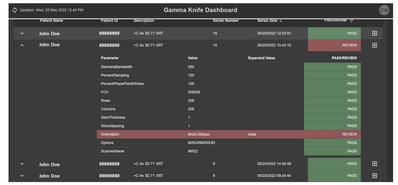
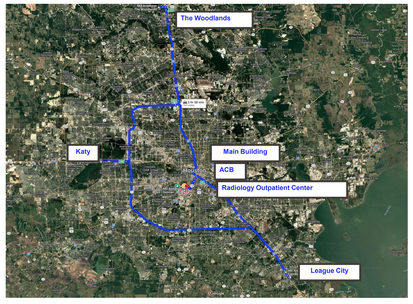


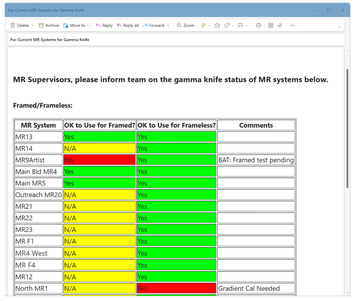
Figure: The online dashboard checking the IDCOM metadata tags to verify that the proper protocol was used.

An online dashboard automatically compares each patient scan to the approved protocol, verifying that all acquisition parameters are correct. This dashboard is reviewed for every patient to ensure protocol compliance and prevent errors that could impact treatment.

Component 4: Daily Scanner Status Email

A fleet of 18 MRI scanners distributed across multiple sites is used for SRS imaging. As scanner performance changes, physicists and MRI technologists must be kept informed of which systems are within tolerance. A daily email communicates scanner status, clearly identifying which units are eligible for SRS imaging.





MR Supervisors, please inform team on the gamma knife status of MR systems below.

Framed/Frameless:

MR System	OK to Use for Framed?	OK to Use for Frameless?	Comments
MR13	Yes	Yes	
MR14	N/A	Yes	
MR9Artist	No	Yes	BAT: Framed test pending
Main Bld MR4	Yes	Yes	
Main MR5	Yes	Yes	
Outreach MR20	N/A	Yes	
MR21	N/A	Yes	
MR22	N/A	Yes	
MR23	N/A	Yes	
MR F1	N/A	Yes	
MR4 West	N/A	Yes	
MR F4	N/A	Yes	
MR12	N/A	Yes	
North MR1	N/A	No	Gradient Cal Needed

Figure: The MRI scanner fleet is distributed across a large geographic area (left). A daily email communicates the SRS eligibility status of each scanner (right)..