ACR Accreditation Update in MRI

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MRI Accreditation Update

1. ACR MRI Accreditation: Overview, History and Role of the Medical Physicist

2. CMS/MIPPA Requirements

3. Other Accreditation Organizations

4. ACR MRI Application Specifics (Whole-body modular, Extremity and Breast)

5. Revised ACR MRI Quality Control Manual (Radiologist, Technologist and Medical Physicist Sections)

6. Accreditation and MRI Safety
ACR MRI Accreditation Program History

www.acr.org/QualitySafety/Accreditation/MRI

Goals of the ACR MRI Accreditation Program are to set quality standards for “best practice” and to help continuously improve the quality of patient care.

Primary components of the ACR program are the evaluation of:

1. Qualifications of all personnel (Physicians, Physicists and Technologists)
2. Equipment performance
3. Effectiveness of quality control measures
4. Quality of clinical images

ACR Milestones

- 1996: Voluntary Whole-body/Cardiac MRI accreditation with “Large” QA phantom

- 2008: Modular program (Head, Spine, MSK, Body, MRA, Cardiac)

- 2008: “Small” phantom for dedicated extremity systems.
  (Note: Not required for MSK module accreditation)

- 2010: Breast MRI Accreditation (Mammography program not MRI program)

- 2012: Required site visit once during each 3-year accreditation cycle
Role of the Medical Physicist


I. Qualifications and Responsibilities of Personnel

II. System Performance Characteristics to be Monitored

   A. Acceptance Testing
   B. Annual Equipment Performance Testing
   C. Quality Control and Safety Program
   D. Written Survey Reports and Follow-up Procedures

MRI Accreditation Program Requirements (7/2/13)


www.acr.org
## ACR Annual Performance Tests
*(Red indicate new requirements.)*

<table>
<thead>
<tr>
<th></th>
<th>Table Positioning, Setup and Scanning</th>
<th>Technologist QC (Weekly)</th>
<th>Medical Physicist/MR Scientist (Annually)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Center (Central) Frequency</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>Transmitter Gain or Attenuation</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>Geometric Accuracy</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>5</td>
<td>High-Contrast Spatial Resolution</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>6</td>
<td>Low-Contrast Detectability</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>7</td>
<td>Artifact Evaluation</td>
<td>X</td>
<td>X</td>
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<tr>
<td>8</td>
<td>Hardcopy (Film) QC (if applicable)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>9</td>
<td>Visual Checklist</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>10</td>
<td>Percent Signal Ghosting (PSG)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Image Intensity Uniformity (PIU)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Magnetic Field Homogeneity</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Slice Position Accuracy</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Slice Thickness Accuracy</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Radiofrequency Coil Checks (SNR for all coils used clinically)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Soft Copy (Monitor) QC (Luminance, uniformity and SMTE)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>MR Safety Program Assessment</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

As part of annual testing, physicist must repeat and evaluate the weekly Tech QC measurements as well as the sequences required for accreditation submission. Note: Interslice RF cross-talk test has been eliminated.
CMS/MIPPA Requirements

The Centers for Medicare and Medicaid Services (CMS/MIPPA)* requires that all facilities providing Advanced Diagnostic Imaging (ADI)** services that are billed under Part B of the Medicare Physician Fee Schedule must be accredited by one of the four CMS approved accreditation organizations by January 1, 2012. Accreditation requirements specifically do not apply to the physician’s image interpretation.

American College of Radiology (ACR)
Joint Commission (JC)
Intersocietal Accreditation Commission (IAC)
RadSite (RS) (2013)

* MIPPA: Medicare Improvements for Patients and Providers Act
** ADI: MRI, CT and Nuclear Medicine/PET
Revised Requirements for Diagnostic Imaging Services

Applicable to hospitals and Critical Access Hospitals
Effective July 1, 2014 (Extended to 2015)
(Very similar to current ACR standards.)

**Standard EC.02.04.03**
The [critical access] hospital inspects, tests, and maintains medical equipment.

A 20. © For [critical access] hospitals that provide magnetic resonance imaging (MRI) services: At least annually, a diagnostic medical physicist or MRI scientist conducts a performance evaluation of all MRI imaging equipment. The evaluation results, along with recommendations for correcting any problems identified, are documented. The evaluation includes the use of phantoms to assess the following imaging metrics:

- High-contrast resolution
- Low-contrast resolution (or contrast-to-noise ratio)
- Geometric or distance accuracy
- Magnetic field homogeneity
- Artifact evaluation

(MRI) services: The annual performance evaluation conducted by the diagnostic medical physicist includes testing of image acquisition display monitors for maximum and minimum luminance, luminance uniformity, resolution, and spatial accuracy.

**Note:** This element of performance does not apply to dental cone beam CT radiographic imaging studies performed for diagnosis of conditions affecting the maxillofacial region or to obtain guidance for the treatment of such conditions.
The IAC Standards and Guidelines for MRI Accreditation

Accreditation Areas

• Cardiovascular MRI
• Breast MRI
• Body MRI (Chest, abdomen, pelvis, extremity)
• Musculoskeletal MRI
• Neurological MRI
• MRA

Key Features

1. Performance referenced to manufacturer’s specifications
2. Medical Physicist qualifications not specified
3. No specific phantom identified
4. Safety Assessment Required
Areas of Accreditation

- Neurologic
- Musculoskeletal
- Body
- Cardiovascular
- Breast Imaging
- MR Angiography (MRA)
- MR Spectroscopy

Key Features

1. Personnel qualifications and performance guidelines similar to ACR.
2. Phantom images may use either ACR or MagPhan SMR170
3. Safety Assessment
The ACR MRI accreditation program requires:

| 20% | 1. Sites to provide breast MR imaging |
| 20% | 2. Magnets to be ≥ 1.0T               |
| 20% | 3. A verification site visit every year |
| 20% | 4. CMS accreditation                  |
| 20% | 5. Annual system performance testing  |
The ACR MRI Accreditation program requires:

1. Sites to provide breast MR imaging
2. Magnets to be $\geq 1.0T$
3. A verification site visit every year
4. CMS accreditation
5. Annual system performance testing

Reference: ACR MRI Accreditation Requirements

ACR Accreditation Application: No Significant Changes

The accreditation process consists of two phases:

**Phase 1:** Account Activation *(Must be completed online.)*

**Phase 2:** Application *(Image submission either online or mailed CDs.)*

For the modular whole-body and extremity magnets the Full Application requires:

- Phantom and Clinical Images
- Physicist’s Equipment Performance Report for each magnet (< 1 year)
  and last quarter QC documents

**Note:** At the present time the Breast MRI application does not require phantom images but does require the Physicist’s Equipment Performance Report and QC documents.
When completed and accepted, you will receive an email indicating that your online “testing package” is available.
ACR Accreditation User Instructions for Electronic Submission of Images

Select submission as Electronic from the drop down.
Phantom Images Required for Accreditation Application: No Change

**Large Phantom**
- Sagittal Localizer
  - TR/TE = 200/20 ms, 25 cm FOV, 256 x 256, 1@20 mm, 1 NEX, 0:56
- ACR T1 Axial Series
  - TR/TE = 500/20 ms, 25 cm FOV, 256 x 256, 11@5 mm slices, 1 NEX, 2:16
- ACR T2 Axial Series
  - TR/TE1/TE2 = 2000/20/80 ms, 25 cm FOV, 256 x 256, 11@5 mm slices, 1 NEX, 8:56
    (same locations as for ACR T1 series)
- Site T1 Brain Series (11@5 mm slices)
- Site T2 Brain Series (11@5 mm slices)

**Small Phantom**
- Sagittal Localizer
  - TR/TE = 200/20 ms, 12 FOV, 152/192, 1@20 mm, 1 NEX, 0:32
- ACR TE Axial Series
  - TR/TE = 500/20 ms, 12 FOV, 152/192, 7@5 mm slices, 1 NEX, 1:16
- ACR T2 Axial Series
  - TE/TE = 2000/80 ms, 12 FOV, 152/192, 7@5 mm slices, 1 NEX, 5:04
- Site T1 Knee Series (7@5 mm slices)
- Site T2 Knee Series (7@5 mm slices)
Large and Small Phantom Test Guidance Document

Phantom Test Guidance

Phantom Test Guidance for Use of the Small MRI Phantom for the MRI Accreditation Program

Available at www.acr.org
**Clinical Examination Choices by Module**

<table>
<thead>
<tr>
<th>Head/Neck</th>
<th>Spine</th>
<th>MSK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain for transient ischemic attack (TIA)</td>
<td>Lumbar Spine</td>
<td>Knee such as for internal derangement</td>
</tr>
<tr>
<td>Internal auditory canal (IAC/temporal bone) for hearing loss</td>
<td>Thoracic Spine</td>
<td>Shoulder such as for internal derangement</td>
</tr>
<tr>
<td>Brain for suspected demyelinating disease*</td>
<td>Cervical Spine*</td>
<td>Wrist such as for internal derangement*</td>
</tr>
<tr>
<td>Pituitary with dynamic contrast enhancement*</td>
<td>Cervical Spine with contrast for intramedullary disease*</td>
<td>Elbow such as for internal derangement*</td>
</tr>
<tr>
<td>Orbits for vision loss*</td>
<td></td>
<td>Forefoot for Morton’s neuroma*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Body</th>
<th>MRA</th>
<th>Cardiac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male pelvis such as for prostate cancer</td>
<td>Brain</td>
<td>Black blood</td>
</tr>
<tr>
<td>Renal</td>
<td>Carotid</td>
<td>Basic</td>
</tr>
<tr>
<td>Hepatobiliary to Include MRCP*</td>
<td>Thoracic aorta</td>
<td>Delayed enhanced cine 1</td>
</tr>
<tr>
<td>Female pelvis such as for uterine or adnexal disease*</td>
<td>Distal peripheral runoff</td>
<td>Delayed enhanced cine 2</td>
</tr>
<tr>
<td></td>
<td>High resolution arch and carotid*</td>
<td>Delayed enhanced cine + black blood*</td>
</tr>
<tr>
<td></td>
<td>Abdomen for renal artery stenosis *</td>
<td></td>
</tr>
</tbody>
</table>

Typical requirements: 4-6 exams per scanner depending upon the number of modules. Exams must include a “specialty” exam.
At the present time there is no specific ACR MRI phantom.

For Breast MRI Accreditation, the Medical Physicist/MR Scientist has the added responsibility of choosing the phantom to be used for the weekly QA measurements and determining the specifics of the QC program.

Currently, the ACR Breast MRI Accreditation application does not require phantom images.

However because of the specific and detailed requirements for the clinical image acquisition parameters, the Medical Physicist has an important roll in the submission process to confirm that the images meet the technical requirements.
Note: Application now only requires submission of a biopsy-proven CA patient. There is currently no specific requirement for phantom images with the breast MRI application. However, the ACR does require submission of most recent Medical Physics report and phantom QA measurements with a phantom. The specifics of the QA program and the phantom is to be determined by the Medical Physicist.
Breast Weekly QC Measurements

- **Daily/weekly QC:**
  - Choice of phantom and action criteria is up to facility. Decision made by “qualified medical physicist/MR scientist in cooperation with the system vendor”.
    - Large ACR phantom in head coil
    - Dedicated breast MR systems may use small ACR phantom in breast coil.
    - Other vendor-supplied phantom
The Medical Physicist will need to help the site determine some of the required information, e.g. slice thickness, phase and frequency-encoding steps and FOV.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>T2-Weighted/Bright Fluid Series</th>
<th>Multi-Phase T1-Weighted Series</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre-Contrast T1</td>
<td>Early Phase (1st) Post-Contrast T1</td>
<td>Delayed Phase (last) Post-Contrast T1</td>
</tr>
<tr>
<td>Sequence name/type</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sequence #</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2D or 3D sequence (check one)</td>
<td>✐ 2D  ☐ 3D</td>
<td>☐ 2D  ☐ 3D</td>
<td>☐ 2D  ☐ 3D</td>
<td>☐ 2D  ☐ 3D</td>
</tr>
<tr>
<td>Slice orientation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acquisition time (min, sec)</td>
<td>min, sec</td>
<td>min, sec</td>
<td>min, sec</td>
<td>min, sec</td>
</tr>
<tr>
<td>Slice thickness (mm) (not interpolated)</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>Interslice gap (mm)</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>Total number of slices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FOV_{phase-encoding} (mm)</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>FOV_{frequency-encoding} (mm)</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>N_p (# of phase-encoding steps)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N_f (# of frequency-encoding steps)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Acquisitions per phase-encoding step (NEX)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TE (msec)</td>
<td>msec</td>
<td>msec</td>
<td>msec</td>
<td>msec</td>
</tr>
<tr>
<td>TR (msec)</td>
<td>msec</td>
<td>msec</td>
<td>msec</td>
<td>msec</td>
</tr>
<tr>
<td>Flip Angle (degrees)</td>
<td></td>
<td></td>
<td>degrees</td>
<td>degrees</td>
</tr>
<tr>
<td>TI (only applicable for STIR sequences)</td>
<td>msec</td>
<td></td>
<td>°</td>
<td>°</td>
</tr>
</tbody>
</table>

For the pre-contrast and post-contrast T1-weighted series, the following parameters must be met:

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Slice Thickness</th>
<th>Gap</th>
<th>Maximum Recommended In Plane Pixel Dimension for Phase and Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagittal, Axial and/or Coronal</td>
<td>≤3 mm</td>
<td>0 mm</td>
<td>≤1 mm</td>
</tr>
</tbody>
</table>
Revised ACR MRI QC Manual

- Minor changes from the 2004 version. Changes primarily for clarification with more detail on testing procedures for both large and small phantoms. There are added optional methods for SNR and field homogeneity and there is a greater emphasis on MRI safety.*

- Updated version to be released in 2014. Electronic with FAQs and annual update

MR Technologist’s Section

Technologist weekly/daily QC tests:

1. Center frequency
2. Table positioning
3. Setup and scanning
4. Geometric accuracy
5. High-contrast resolution
6. Low-contrast detectability
7. Artifact analysis
8. Laser camera QC (if applicable)
9. Visual checklist
10. Laser Light Alignment
11. Ensure Universal-Standard Precautions for infection control are followed

New (large and small phantoms)
Weekly Visual Inspection

• Check patient table, patient communication, patient “panic button”, table movement, laser alignment and all light indicators

“If the table positioning system functions properly and the center of the sagittal image is within ±2 mm of the central grid structure on the phantom, enter “YES” in column 2 “Table OK?” of the Data Form for Weekly MRI Equipment Quality Control.”

• Check RF room integrity (doors contacts and windows)

• Check emergency cart, safety lights, signage, equipment for MR compatibility and all patient monitors

• Check all RF coils for damage and cable integrity
The ACR MRI accreditation program requires the technologist to make a weekly assessment of:

|----|-----------------------------|-----------------------------|-------------------------------|--------------------------------|----------------------------|
The ACR MRI accreditation program requires the technologist’s to make a weekly assessment of:

1. Slice thickness accuracy
2. Percent image uniformity
3. Low-contrast detectability
4. Magnetic field homogeneity
5. Five-gauss line location

Reference: ACR website www.acr.org
ACR MRI Quality Control Manual
Technologist’s Section
Establishing Action Limits for Technologist’s QC

Specific action limits are the responsibility of the medical physicist but must be at least as restrictive as the ACR recommended guidelines.

How to start?

1. Service engineer should run all vendor tests to assure system is performing to vendor specifications
2. Establish baseline during acceptance testing (AAPM Report 100)
3. Collect “weekly” QC data for at least 10 days
   - Central frequency
   - Transmitter gain / attenuation
   - Geometric accuracy
   - High contrast resolution
   - Low contrast resolution
4. Record as “Baseline” in Technologist’s QC notebook
Acceptance Testing: Image Performance
(Similar accreditation annual performance tests.)

1. **Static Magnetic Field: Uniformity and Drift**
2. **RF System**
3. **Gradient System**
4. **System measurements**
   - Slice thickness and position accuracy
   - Signal-to-Noise Ratio (SNR)
   - Percent Image Uniformity (PIU)
   - Percent Signal Ghosting (PSG)
   - High-contrast spatial resolution
   - Low-contrast detectability

5. **Advanced MR System Tests**
   - Ultrafast (EPI) Tests (N/2 ghosting and spatial distortion)
   - Spectroscopy Tests (VOI position accuracy and spectral quality)
QC Phantom Selection

The selection of the phantom used for routine QC is the responsibility of the medical physicist. The phantom must be capable of providing assessment of the JC/ACR/IAC/RS required parameters and will typically dependent upon the type of scanner:

- Whole body scanners – Large Phantom
- Extremity (Breast) scanners – Small Phantom

ACR Large Phantom: 190 mm  
ACR Small Phantom: 100 mm
Establishing QC Action Limits

(Determined by the medical physicist. Must be as restrictive as ACR guidelines.)

1. Central frequency expressed in ppm (typically $\pm 1.5$ ppm)
   
   $(1.5 \text{ ppm @ 1.5T} \sim 96 \text{ Hz or determined by the medical physicist})$

2. Transmitter Gain or Attenuation (determined by medical physicist)

3. Geometric Accuracy ($\pm 2$ mm)

4. High-Contrast Resolution (at least 1 mm)

5. Low-Contrast Detectability (determined by medical physicist)

6. Artifacts (any artifacts should be noted and image saved)

   **Common approach:** Determine mean and standard deviation (SD).

   May need to use $\pm 2$SD depending upon the system.
Annual Magnetic Field Homogeneity Testing
(Optional methods described in the revised manual.)

- Spectral FWHM with large sphere (Only global sensitivity)
- Phase-Difference Method (Provides planar map image)
- Phase-Map Method (Provides planar map image)
- Bandwidth-Difference Method (Global sensitivity)
  (Chen, et al Med. Phys. 33 (11), 2006. Note: only sensitive along frequency axis.)

Alternative: For systems that do not allow any of these methods. One may use the service engineer’s most recent shim report (< 6 month).
Spheres are provided by some vendors and should be used for the homogeneity tests. The sphere should be placed at the field isocenter.

The homogeneity should be specified for the largest diameter of the spherical volume (DSV) available.

\[
\text{FWHM(ppm)} = \frac{\text{FWHM(Hz)}}{63.87 \, B_0(T)}
\]
Phase-Difference Method

\[ \Delta B_0 = (\Delta \phi / \gamma)/(TE_1 - TE_2), \]

where the \( \Delta B_0 \) is in mT, \( \Delta \phi \) is the phase difference in radians, \( \gamma \) is the gyromagnetic ratio and the TE values are in units of seconds. Use either a 3D Gradient Echo sequence or repeat the measurements for each orthogonal plane. The phase-difference method provides a spatial map of the field homogeneity within the chosen plane.

Note: Consult system manufacturer to determine the units used for the value of the phase pixels (e.g. radiansX1000)
Phase-Map Method
(Revised Manual)

Gradient Echo Sequence: \( TE \sim 1/\text{resonance frequency (ppm)} \)
\( \text{e.g. 1 ppm @ 1.5T = 1/63 Hz = 15.6 ms} \)

\[ \begin{align*}
\text{TE} = 10 \text{ ms} & \sim 0.8 \text{ ppm/transition} \\
\text{TE} = 20 \text{ ms} & \sim 0.4 \text{ ppm/transition}
\end{align*} \]

The field homogeneity \( (\Delta B_0) \) is determined by counting the number of transitions and then multiplying by the ppm/transition for the specific TE.
Axial  
Sagittal  
Coronal

\[
H_B(\text{ppm}) = \frac{BW_1 \cdot BW_2 \cdot (x'_1 - x'_2)}{\gamma \cdot B_0 \cdot \text{FOV}_x (BW_2 - BW_1)}
\]

Note: The BW-difference method is sensitive to homogeneity in the frequency-encode direction only and thus should be repeated for all three orthogonal axes at largest DSV.

The ACR MRI accreditation program requires that field homogeneity be assessed:

- 20% 1. As part of the weekly QA
- 20% 2. When a new coil is purchased
- 20% 3. Only at the time of installation
- 20% 4. At each annual performance testing
- 20% 5. By the vendor’s service engineer
The ACR MRI accreditation program requires that field homogeneity be assessed:

1. As part of the weekly QA
2. When a new coil is purchased
3. Only at the time of installation
4. At each annual performance testing
5. By the vendor’s service engineer

Reference: ACR MRI Accreditation Requirements

ACR Large Phantom Analysis

Five sequences: ACR T1, Dual-Echo T2, and Site T1 and T2
(SE 50/500 and SE 20-80/2000 ms, 25 cm, 256X256, multi-slice (11 at 5mm), 1 NEX)

Localizer: Geometric Accuracy (z)

#1) Slice thickness and position, geometric accuracy, high contrast resolution
#5) Geometric accuracy (x,y)
#7) Percent image uniformity (PIU), Percent signal ghosting (PSG)
#8-11) Low contrast object detectability (LCD), and slice position (in #11)

Images courtesy of E.F. Jackson, PhD
Volume Coil SNR (two SNR methods in revised manual)

(Two SNR methods in revised manual: Single-image or Image-difference)

Assess for all coils used clinically with a uniform phantom.

1. Single-Image Methods

   Note: Intensity correction algorithms should be off

   a. ACR 2004 Original:  \( \text{SNR} = \frac{\text{Mean Signal}}{\sigma_{\text{air}}} \)

   b. NEMA Method 4: \( \text{SNR} = 0.655 \times \frac{\text{Mean}}{\sigma_{\text{air}}} \)

2. Image-Difference Method

   Image-Difference Method: NEMA Method 1

NEMA MS 1-2008: Determination of Signal-to-Noise Ratio in Diagnostic Magnetic Resonance Images (Method 4)

Note: No background subtraction and NEMA (4) X 0.655 for Rician noise correction.
For Single-image methods, image intensity correction should be off e.g. SCIC, CLEAR and PURE. The intensity correction algorithm will significantly affect the background noise ($\sigma_{\text{air}}$) estimate and thus the calculated SNR.
Image-Difference Method (NEMA Method 1*)


*NEMA MS 1-2008: Determination of Signal-to-Noise Ratio in Diagnostic Magnetic Resonance Images (Method 1)
Window and level to make sure ROIs are in the background noise.

(Warping of image space due to gradient nonlinearity corrections may affect ROI location.)
Gradient Distortion Correction Effect on Spatial Resolution

Without Correction

With Correction
High Contrast Spatial Resolution

- Turn off gradient distortion correction algorithm (if possible)
- Magnify by 2-4 X
- Use UL for horizontal resolution and LR for vertical resolution
- Must be able to resolve 1.0 mm holes vertically and horizontally
- Set WW and WL for visualization

Criterion: 1.0 mm
When measuring SNR in multi-element volume coils, it is recommended that:

<table>
<thead>
<tr>
<th>20%</th>
<th>1. Only the ACR phantom be used</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td>2. Intensity-correction algorithms be used</td>
</tr>
<tr>
<td>20%</td>
<td>3. Largest available image matrix be used</td>
</tr>
<tr>
<td>20%</td>
<td>4. Be performed by the service engineer</td>
</tr>
<tr>
<td>20%</td>
<td>5. Each individual element be tested</td>
</tr>
</tbody>
</table>
When measuring SNR in multi-element volume coils, it is recommended that:

1. Only the ACR phantom be used
2. Intensity-correction algorithms be used
3. Largest available image matrix be used
4. Be performed by the service engineer
5. Each individual element be tested

Volume Coil PIU and PSG: (2014 ACR Manual)

Percent Image Uniformity: PIU (same)

\[ PIU = 100 \cdot \left( 1 - \frac{\text{Max ROI} - \text{Min ROI}}{\text{Max ROI} + \text{Min ROI}} \right) \]

Percent Signal Ghosting: PSG (same)

\[ PSG = 100 \cdot \left( \frac{\text{(Left + Right)} - (\text{Top + Bottom})}{2 \cdot \text{Mean Signal}} \right) \]

ACR Small Phantom
(Extremity Systems)

Sag localizer: Geometric accuracy

#1) Slice thickness and position, geometric accuracy, high contrast resolution

#3) Geometric accuracy

#5) PIU, ghosting (PSG)

#6-7) LCD

Five Sequences
1) ACR Sagittal (20/200)  4) Site T1 (knee)
2) ACR T1 SE (20/500)   5) Site T2 (knee)
3) ACR T2 SE (80/2000)
## ACR Guidelines for Phantom Scans

### Large Phantom

*ACR Limits: Unchanged*

(FOV = 25 cm, 256x256)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensional accuracy (Sagittal)</td>
<td>148 ± 2 mm</td>
</tr>
<tr>
<td>Dimensional accuracy (Axial)</td>
<td>190 ± 2 mm</td>
</tr>
<tr>
<td>Slice Thickness</td>
<td>5 ± 0.7 mm</td>
</tr>
<tr>
<td>Slice Position</td>
<td>≤ 5 mm</td>
</tr>
<tr>
<td>Image Uniformity (PIU)</td>
<td>≥ 87.5% (&lt; 3T)</td>
</tr>
<tr>
<td></td>
<td>≥ 82.0% (3T)</td>
</tr>
<tr>
<td>Percent Signal Ghosting</td>
<td>≤ 2.5%</td>
</tr>
<tr>
<td>High-contrast Resolution</td>
<td>1 mm</td>
</tr>
<tr>
<td>Low-contrast Detectability Score</td>
<td>≥ 9 (&lt;3T)</td>
</tr>
</tbody>
</table>

### Small Phantom

*ACR Limits: Unchanged*

(FOV = 12 cm, 152x192)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensional accuracy (Sagittal)</td>
<td>100 ± 2 mm</td>
</tr>
<tr>
<td>Dimensional accuracy (Axial)</td>
<td>100 ± 2 mm</td>
</tr>
<tr>
<td>Slice Thickness</td>
<td>5 ± 0.7 mm</td>
</tr>
<tr>
<td>Slice Position</td>
<td>≤ 5 mm</td>
</tr>
<tr>
<td>Image Uniformity (PIU)</td>
<td>≥ 87.5% (&lt; 3T)</td>
</tr>
<tr>
<td>Percent Signal Ghosting</td>
<td>≤ 2.5%</td>
</tr>
<tr>
<td>High-contrast Resolution</td>
<td>0.8 mm</td>
</tr>
<tr>
<td>Low-contrast Detectability Score</td>
<td>≥ 9 (&lt;3T)</td>
</tr>
</tbody>
</table>
Surface Coil SNR Measurements: Changes

Original manual recommendation was to use phantom geometry that best matched the coil and to measure the Maximum SNR. In order to improve year-to-year reproducibility, recommendation is to measure the Mean SNR and to use the largest ROI’s possible for both signal and background.
The revised ACR MRI Manual recommends that if possible the images from each coil element be reconstructed and evaluated individually to check for malfunctioning elements. This is increasingly important with high-density arrays. A single SNR and/or uniformity measurement often will not detect a single bad element (or even a few bad elements). Some scanners provide an easy option, selectable by the technologist or other operator, to allow for the reconstruction and display of the image from each element. On other systems, service or research mode access is required.

PIU = 93%

Dead Coil Element in 8-channel array

Images Courtesy of Ed Jackson
Soft Copy Displays (no changes)

Four Tests:

1. Max and Min luminance ($L_{\text{max}}$ and $L_{\text{min}}$)
2. Luminance uniformity
3. Resolution using SMPTE pattern
4. Spatial accuracy (SMPTE)

Specifications:

1. Max luminance ($WL/WW = \text{min}$): $> 90 \text{ Cd/m}^2$
2. Min luminance: $< 1.2 \text{ Cd/m}^2$
3. Uniformity: $\%$ difference $= 200 \times \frac{L_{\text{max}} - L_{\text{min}}}{L_{\text{max}} + L_{\text{min}}}$
4. Resolution: display bar pattern of $100\%$ contrast
5. Spatial accuracy: lines straight within +/- 5mm
ACR Medical Physicist’s Site Safety Assessment (Checklist)

(All new section)

• Site Access Restrictions (MR Zones)
• Documented MR Safety Education/Training for all personnel
• Patient and non MR Personnel Screening
• Pediatric Patient Policy
• Designated MR Safety Officer
• Disaster Policy
• Quench Policy
• Cryogen Safety Policy
• Acoustic Noise Policy
• Pregnancy Policy
• Contrast Agent Safety Policy
• Sedation Policy
• Thermal Burns Policy
• Emergency Code Procedures
• Device and Object Screening and designation of MR Safe/MR Conditional status
• Procedures for Reporting MR Safety Incidents or Adverse Incidents
• Patient Communication
• Infection Control

Criteria for Compliance

1. Written policies are present and are being reviewed and updated on a regular basis.
2. Facility has appropriate signage and methods of controlled access.
   Documentation of regular MR safety training for each facility staff member
Joint Commission MRI Safety Performance Standards

Revised Requirements for Diagnostic Imaging Services

Standard EC.02.01.01
The [critical access] hospital manages safety and security risks.

Elements of Performance for EC.02.01.01

A.14. For [critical access] hospitals that provide magnetic resonance imaging (MRI) services, the [critical access] hospital manages safety risks in the MRI environment associated with the following:
- Patients who may experience claustrophobia, anxiety, or emotional distress
- Patients who may require urgent or emergent medical care
- Patients with medical implants, devices, or imbedded foreign objects (such as shrapnel)
- Ferromagnetic objects entering the MRI environment
- Acoustic noise

A.16. For [critical access] hospitals that provide magnetic resonance imaging (MRI) services, the [critical access] hospital manages safety risks by doing the following:
- Restricting access of everyone not trained in MRI safety or screened by MRI-trained staff from the scanner room and the area that immediately precedes the entrance to the MRI scanner room.
- Making sure that these restricted areas are controlled by and under the direct supervision of MRI-trained staff.
- Posting signage at the entrance to the MRI scanner room that conveys that potentially dangerous magnetic fields are present in the room. Signage should also indicate that the magnet is always on except in cases where the MRI unit, by its design, can have its magnetic field routinely turned on and off by the operator.

A.25. For [critical access] hospitals that provide magnetic resonance imaging (MRI) services, the [critical access] hospital verifies and documents that technologists who perform MRI examinations participate in ongoing education that includes annual training on safe MRI practices in the MRI environment, including the following:
- Patient screening criteria that address ferromagnetic items, medical implants and devices, and risk for nephrogenic systemic fibrosis (NSF)
- Proper patient positioning activities to avoid burns
- Equipment and supplies that have been determined to be acceptable for use in the MRI environment (MRI safe or MR conditional)*
- MRI safety response procedures for patients who require urgent or emergent medical care
- MRI equipment emergency shutdown procedures
- Patient hearing protection
- Management of patients with claustrophobia, anxiety, or emotional distress

*Terminology for defining the safety of items in the magnetic resonance environment is provided in ASTM F2503 Standard Practice for Marking Medical Devices and Other Items for Safety in the Magnetic Resonance Environment (http://www.astm.org).

Elements of Performance for PI.01.01.01

A.46. For [critical access] hospitals that provide magnetic resonance imaging (MRI) services, the [critical access] hospital collects data on patient burns that occur during MRI exams.

A.47. For [critical access] hospitals that provide magnetic resonance imaging (MRI) services, the [critical access] hospital collects data on the following:
- Incidents where ferromagnetic items entered the MRI scanner room
- Injuries resulting from the presence of ferromagnetic items in the MRI scanner room
As part of the annual performance testing, the medical physicist is expected to perform all of the following **except**:

<table>
<thead>
<tr>
<th>20%</th>
<th>1.</th>
<th>Site safety assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td>2.</td>
<td>Repeat of weekly QA tests</td>
</tr>
<tr>
<td>20%</td>
<td>3.</td>
<td>Static-field gradient measurement</td>
</tr>
<tr>
<td>20%</td>
<td>4.</td>
<td>Magnetic field homogeneity test</td>
</tr>
<tr>
<td>20%</td>
<td>5.</td>
<td>SNR for all clinical coils</td>
</tr>
</tbody>
</table>
As part of the annual equipment performance testing, the medical physicist is expected to perform all of the following except:

1. Site safety assessment
2. Repeat of weekly QA tests
3. Static-field gradient measurement
4. Magnetic field homogeneity test
5. SNR for all clinical coils

Reference: ACR MRI Accreditation Requirements

Conclusion and Comments

• The revised ACR MRI Quality Control Manual has relatively minor changes from the 2004 version. Specific tests are basically the same but with more options and better descriptions.

• There is a increased emphasis on MRI safety and infection control to minimize patient risk.

• An attempt was made to embrace NEMA standards, Joint Commission recommendations and AAPM Report 100.

• Currently the revised manual does not identify a specific method for testing parallel imaging. However, when a generally accepted method is identified, it will be incorporated into the electronic manual by means of an annual update.