Breast MRI Quality Control

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Educational Objectives

• Discuss the importance of breast MRI quality control (QC).

• Provide an overview of the new ACR Breast MRI Accreditation program (BMRAP) including quality control requirements.

• Describe MRI system and coil designs currently available for breast MR imaging

• Discuss breast coil quality control procedures
Importance of breast MR QC

Quality control of MRI systems used for diagnostic breast MR imaging and biopsy guidance

- Is important to ensure production of high quality images by evaluating whether MRI scanner and coils used for breast imaging are performing consistently over time.
- Should be part of a comprehensive MRI quality control program.
- May be required to satisfy accreditation program requirements

ACR Breast MRI Accreditation Program

ACR Breast Magnetic Resonance Imaging Accreditation Program (BMRAP) launched in May 2010 under breast imaging accreditation programs (mammography, stereotactic breast biopsy, and breast ultrasound).

- Separate from the ACR MR Accreditation Program (MRAP)
- Provides accreditation for MR systems used for breast imaging:
  - Dedicated breast MRI systems or
  - Whole body MRI systems with
    - detachable table-top breast coil
    - dedicated tables with integrated breast coils
Breast MRI RF Coils

www.auroramri.com

www.sentinellemedical.com

Philips MammoTrak SENSE 16 Channel

Invivo 3T Precision Breast Array 8 Channel

Guidance documents

www.acr.org

Breast Magnetic Resonance Imaging (MRI) Accreditation Program Requirements

Breast MRI Accreditation Program Clinical Image Quality Guide

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

Accreditation Fees
Facilities must submit the appropriate fee with their application. All fees are non-refundable and subject to change without notice.

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Fees</th>
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</thead>
<tbody>
<tr>
<td>Accreditation (Initial cycle and renewal)</td>
<td>$2,400 for the first unit</td>
</tr>
<tr>
<td></td>
<td>$2,300 each additional unit at the same geographic location</td>
</tr>
<tr>
<td>Repeat</td>
<td>$700 for each unit</td>
</tr>
<tr>
<td>Reinstall/Corrective Action Plan</td>
<td>$2,400 for the first unit</td>
</tr>
<tr>
<td>Add units (mid cycle)</td>
<td>$2,300 each additional unit at the same geographic location</td>
</tr>
<tr>
<td>Replacement Certificate</td>
<td>$1,400 for each unit</td>
</tr>
<tr>
<td></td>
<td>$65 per certificate</td>
</tr>
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</table>

Personnel Qualifications – Radiologist

Initial qualifications:
- Certification in Radiology or Diagnostic Radiology (ABR, American Osteopathic Board of Radiology, Royal College of Physicians and Surgeons of Canada or Le College des Medecins du Quebec)
  AND
- Supervision, interpretation and reporting of 150 breast MRI exams in last 36 months or 100 breast MRI exams in a supervised situation.
  OR
  Not Board Certified
- Completion of an ACGME or AOA approved diagnostic radiology residency program
  AND
- Interpretation and reporting of 100 breast MRI exams in the last 36 months in a supervised situation.
**Personnel Qualifications – Radiologist**

AND

15 hours of Cat 1 CME in MRI (including clinical applications of MRI in breast imaging, MRI artifacts, safety and instrumentation in the last 36 months.

**Continuing Experience:**
Upon renewal, 75 breast MRI examinations in prior 24 months.

**Continuing Education:**
5 hours of Category 1 CME in breast MRI in the prior 36 months.

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**Personnel Qualifications – Technologist**

**Initial qualifications:**

1. Registered in MRI (ARRT, ARMRIT, or CAMRT)
2. OR Registered in radiography by ARRT and/or unlimited state license, and 6 months supervised clinical MRI scanning experience.
3. OR Associate’s or Bachelor’s degree in allied health field and certification in another clinical imaging field and 6 months supervised clinical MRI scanning experience.
   
   AND
   
   • Licensure in state in which he/she practices (if required for MRI techs)
   • Supervised experience in breast MRI
   
   AND
   
   • Supervised experience in the IV administration of MR contrast (if performed by the technologist)
Personnel Qualifications –
Technologist

Continuing Experience:
Upon renewal, 50 breast MRI examinations in prior 24 months.

Continuing Education:
All:
• 24 hours of CE every 2 years
• CE includes credits pertinent to the technologist's ACR accredited clinical practice

Registered technologists:
• CE in compliance with requirements of certifying organization
State licensed technologists, all others:
• CE relevant to imaging and the radiologic sciences, patient care

Personnel Qualifications –
Medical Physicist/MR Scientist

Initial qualifications
Medical Physicist:
1. Board Certification in Radiological Physics or Diagnostic Radiological Physics (ABR), in MRI Physics (ABMP), or in Diagnostic Radiology Physics or MRI Physics (CCPM)
2. Not board certified: graduate degree in relevant fields and formal course work in biological sciences and 3 years documented experience in a clinical MRI environment

MR Scientist:
• Graduate degree in a physical science involving nuclear MR or MRI
• 3 years experience in a clinical MRI environment.
### Personnel Qualifications – Medical Physicist/MR Scientist

#### Continuing Experience:
Upon renewal, 2 MRI unit surveys in prior 24 months.

#### Continuing Education:
Upon renewal, 15 CEU/CME (half must be Category 1) in the prior 36 months (must include credits pertinent to the accredited modality).

<table>
<thead>
<tr>
<th>Must be familiar with MRI safety, FDA guidance for MR diagnostic devices, other regulations pertaining to the performance of the equipment being monitored.</th>
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<tbody>
<tr>
<td>Be knowledgeable about MR physics, MRI technology, including function, clinical uses, performance specifications of MRI equipment, calibration processes and limitations of the performance testing hardware, procedures, and algorithms.</td>
</tr>
<tr>
<td>Working understanding of clinical protocols and optimization. Maintain proficiency in CE programs to ensure familiarity with current concepts, equipment, and procedures.</td>
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</table>

[www.acr.org](http://www.acr.org) Breast MRI Accreditation Program Requirements, 5/10/2010
ACR Breast MRI Accreditation Program

- Annual and acceptance testing requirements
- Technologist QC requirements
- MRI Safety policies and practices
- Periodic maintenance and documentation

→ same as for MRI Accreditation Program

BMRAP Clinical Images

- Facilities must submit clinical images and corresponding data for each magnet performing breast MRI* examinations at their site.
- Dedicated bilateral breast coil capable of simultaneous bilateral imaging.
- Facilities performing breast MRI must have the capacity to perform mammographic correlation, directed breast ultrasound and MRI-guided intervention, or create a referral arrangement with a cooperating BMRAP accredited facility that could provide these services.
- 45 days to acquire clinical exams
- No phantom image submission is required at this time.
Submit 2 bilateral breast MRI cases from different patients

1. Known, enhancing, biopsy-proven carcinoma
2. BI-RADS category 1 (negative) or 2 (benign findings)

Cases may not be older than 2 months

Exams must include these 4 sequences:

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Criteria</th>
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<tbody>
<tr>
<td>T2-Weighted/Bright Fluid Series</td>
<td>• Adequate SNR/not too grainy</td>
</tr>
<tr>
<td></td>
<td>• Sufficient bright fluid contrast</td>
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<tr>
<td>Multi-Phase T1-Weighted Series:</td>
<td></td>
</tr>
<tr>
<td>Pre-Contrast T1</td>
<td>• Adequate SNR/not too grainy</td>
</tr>
<tr>
<td>Early Phase (first) Post-Contrast T1</td>
<td>• Adequate SNR/not too grainy</td>
</tr>
<tr>
<td></td>
<td>• Completed within 4 minutes of completion of injection</td>
</tr>
<tr>
<td></td>
<td>• Technical factors match pre-contrast T1</td>
</tr>
<tr>
<td>Delayed Phase (last) Post-Contrast T1</td>
<td>• Adequate SNR/not too grainy</td>
</tr>
<tr>
<td></td>
<td>• Technical factors match pre-contrast T1</td>
</tr>
</tbody>
</table>
BMRAP Clinical Images

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>

At least 2 ACR radiologist reviewers will score the 5 categories listed in the table below. See the ACR Breast MRI Accreditation Clinical Image Quality Guide for more information.

- Pulse sequences and image contrast
- Positioning and anatomic coverage
- Artifacts
- Spatial and temporal resolution
- Exam identification

BMRAP Quality Control Program

- QC program identical to MRAP.
  - Acceptance, annual, post-upgrade/repair testing, including annual testing of all RF coils
- 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
ACR MR Accreditation Phantoms

Manufacturer: J.M Specialty Parts

$1050 “large phantom”

$780 “small phantom”

Breast Coil QC
Breast MRI RF Coils

- Multiple configurations to allow imaging in unilateral or bilateral modes.
- Multi-channel: 8, 16, 32 independent channels
  - Smaller elements increase SNR
  - Multiple elements provide anatomical coverage - fixed or adjustable positions
  - Allows use of parallel imaging to improve imaging speed or “trade” speed for increased resolution or SNR.
- RF receive-only
- multiple transmit RF (Philips Achieva 3.0 TX)

Breast RF Coil Quality Control

To establish baseline coil performance in order to monitor coil performance over time.

- Coil inspection
- Signal-to-noise ratio (SNR)
- Signal uniformity
- Phased array coils: compare SNR for individual channels
- Artifact evaluation (including ghosting)
  - Using QC protocol
  - Using clinical protocol
Coil testing:

- Important to test coils:
  - after installation of new scanner or new coils
  - annually during physics testing
  - whenever artifacts or coil problems occur

- Manufacturers provide a coil manual for each coil
  - includes description of clinical use of the coil
  - may include detailed description of coil test procedure
  - may include pass/fail limits
  - may only say “establish baseline and monitor over time”

Coil inspection

- Inspect coil, cables, cable insulation, ports and connectors for damage
- Could present a safety issue or result in low SNR or image artifacts.
Breast RF Coil Quality Control

Artifact evaluation
- Evaluate images acquired using coil QC protocol
- To troubleshoot artifacts observed on patient images may acquire images of QC phantom using clinical protocol.

Breast RF Coil Quality Control

Coil testing:
- Test all available coil configurations (bilateral, unilateral).
- Note any error messages that occur during scanning.
- In our experience the vendor is more likely to respond to coil QC failure when manufacturer’s QC procedure is followed.

Uniformity:
- Follow procedure in 2004 ACR MRI QC Manual (min, max signal intensity within small ROI)
Breast RF Coil Quality Control

Consistent scan/measurement methods:

Identical phantom and positioning within coil
  • Homogeneous phantom (sphere, cylinder, custom)
  • ACR or other phantom

Identical scan parameters:
  • Pulse sequence, timing parameters, slice thickness and position, matrix, FOV, receive bandwidth, etc
  • Record center frequency, transmit gain/attenuation, receiver gains

Identical measurement methods, ROI positions
  • SNR, signal uniformity, ghosting, stability tests
  • Evaluation of channel performance
  • Helpful to acquire screen capture of ROI positions and photograph phantom setup

SNR Methods

Signal
  Signal measured in ROI within magnitude image

Noise
  1. Noise measured in background area of signal image (in air) free of artifacts.
  2. Noise measured in “pure noise” image acquired with no RF excitation.
  3. NEMA approach: Noise measured in subtraction image:
      2 signal images acquired with identical protocol and prescan parameters (center frequency, transmit gain or attenuation, receiver gains).

\[
SNR = \frac{0.655\bar{S}}{\sigma_{bg}} \\
SNR = \frac{0.655\bar{S}}{\sigma_{noise}} \\
SNR_{NEMA} = \frac{\bar{S}}{\sigma_{sub}} \sqrt{2}
\]

0.655 factor: noise distribution in magnitude image is Rician (not Gaussian)

Examples of Breast Coil QC procedures

Breast RF Coil Quality Control

GE HD 8 channel phased array (1.5T, 3T)
- Automated QC procedure requires careful positioning/landmarking
- Custom phantom
- NEMA subtraction
- SNR of individual elements
- Pass/fail results
Breast RF Coil Quality Control

Images acquired with individual coil elements

Breast RF Coil Quality Control

Operator's Manual
Model BBC-127

Precision Breast Array Coil for GE Signa 3.0T MRI System
Breast RF Coil Quality Control

Signal ROI = 2cm x 2cm
Noise ROI = 20cm x 10cm
Place ROI as shown on next page.

Calculate Signal-to-Noise Ratio (SNR) using the following formula:

\[ \text{SNR} = \frac{\text{Average of Signal Mean}}{\text{Standard Deviation of Noise}} \]

Sample Data:

\[ \text{SNR} = \frac{3066.18 + 2976.74}{2} / \frac{3.01 + 4.25}{2} = 836.113 \]

The SNR should be at least 800. If the SNR is lower than 800 ensure that the specified phantom is being used prior to contacting your Bruker Representative.

<table>
<thead>
<tr>
<th>Typical Pre-scan Values</th>
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<tr>
<td>P, P, P</td>
</tr>
<tr>
<td>TG</td>
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</table>
Breast RF Coil Quality Control

www.sentinellemedical.com

Bilateral imaging mode

Unilateral biopsy mode
Bilateral Imaging mode

Consistent positioning of QC phantoms and coils

Unilateral Interventional mode
Breast RF Coil Quality Control

- Signal ROI: SE T1, unilateral and bilateral imaging modes
- Noise image (no RF excitation)
**Breast RF Coil Quality Control**

Small ACR phantoms
Bilateral mode

Image courtesy of R. Price, PhD

SE, Philips Achieva 1.5T, 16 channel breast array

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**Breast RF Coil Quality Control**

Small ACR phantom
Unilateral mode

Image courtesy of R. Price, PhD

SE, Philips Achieva 1.5T, 16 channel breast array
Acknowledgements

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References


