ACR Breast MRI Accreditation Program - DRAFT
Donna M. Reeve, MS, DABR, DABMP
Department of Imaging Physics

Educational Objectives
- Provide an overview of the ACR Breast MRI Accreditation Program (BMRAP) including personnel qualifications, equipment requirements, the quality control program and clinical image quality requirements.
- Discuss the role of the medical physicist/MRI scientist in the BMRAP application process.
- Provide clinical examples illustrating common breast MRI artifacts and image quality issues.

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.sentinellemedical.com
- www.auroramri.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

Accreditation fees

www.acr.org  Breast MRI Accreditation Program Requirements, 11/22/2011

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.
**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 – Medical Physicist/MR Scientist**

**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 – 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**

**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).
Personnel Qualifications – Medical Physicist/MR Scientist

- Must be familiar with MRI safety, FDA guidance for MR diagnostic devices, other regulations pertaining to the performance of the equipment being monitored.
- 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.
- Working understanding of clinical protocols and optimization. Maintain proficiency in CE programs to ensure familiarity with current concepts, equipment, and procedures.

Personnel Qualifications – Medical Physicist/MR Scientist

- Must be familiar with MRI safety, FDA guidance for MR diagnostic devices, other regulations pertaining to the performance of the equipment being monitored.
- 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.
- Working understanding of clinical protocols and optimization. Maintain proficiency in CE programs to ensure familiarity with current concepts, equipment, and procedures.

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

Breast MRI Quality Control

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

Breast MRI QC

Physicist:

- MRI system performance evaluation after scanner installation, annually and following major repair or hardware/software upgrade
- Annual QC of all RF coils (including breast MRI coils)

Service engineer:

- Periodic/preventative maintenance (PM). Frequency defined in service contract

MRI technologist:

- Daily/weekly phantom scans
Any field strength
Must accredit all MR systems at the facility that are used to perform diagnostic breast MR imaging
Does not include:
- Dedicated systems used for radiation therapy treatment planning
- Breast biopsy only systems
- Interventional MRI systems

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

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

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.

BMRAP Clinical Images

Submit one bilateral breast MRI case

1. Known, enhancing, biopsy-proven carcinoma
2. BI-RADS category 1 (negative) or 2 (benign findings) No longer required

Cases may not be older than 6 months from the date on the Testing Memorandum

BMRAP Clinical Images

Exams must include these 4 sequences:

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Criteria</th>
</tr>
</thead>
</table>
| T2-Weighted/Bright Fluid Series | Adequate SNR not too granary  
Sufficient bright fluid contrast |
| Multi-Phase T1-Weighted Series: | Adequate SNR not too granary  
Completed within 4 minutes of completion of injection  
Technical factors match pre-contrast T1 |
| Pre-Contrast T1 | Adequate SNR not too granary  
Technical factors match pre-contrast T1 |
| Early Phase (bdl): Post-Contrast T1 | Adequate SNR not too granary  
Technical factors match post-contrast T1 |
| Delayed Phase (bdl): Post-Contrast T1 | Adequate SNR not too granary  
Technical factors match post-contrast T1 |

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.

<table>
<thead>
<tr>
<th>Sequence Acquisition Plane</th>
<th>Slice Thickness</th>
<th>Gap</th>
<th>Maximum in Plane Pixel Dimension for Phase and Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagittal, axial, coronal, and/or slightly oblique</td>
<td>≤0.5 mm</td>
<td>0 mm</td>
<td>≤1.5 mm</td>
</tr>
</tbody>
</table>

BMRAP Clinical Images

www.acr.org  Breast MRI Accreditation Program Requirements, 11/22/2011
**Breast MR Image Quality**

**Challenges:**
- Adequate SNR: ACR: “not too grainy”
- Good spatial resolution
  - ≤ 1mm x 1mm in-plane resolution
  - ≤ 3mm slice thickness
- Temporal resolution dynamic series (60-90 sec/phase)
- Absence of (or minimal) artifacts
- Effective, uniform fat suppression

**SNR**

Potential causes of low SNR:
- Low field strength
- Poor Coil connection
- Coil element failure
- Incorrect center frequency selection
- Protocol parameters:
  - Small voxels (large matrix, small FOV, thin slices)
  - trade-offs: speed, SNR, resolution

\[
\text{SNR} = \frac{p_{\text{ref}} \cdot \text{FOV}_x \cdot \text{FOV}_y}{\sqrt{N_x \cdot N_y \cdot \Delta v_{\text{reso}}}} \cdot \delta \cdot \sqrt{\text{B}_0 \cdot f}
\]

**Breast MR Image Quality**

**Category A: pulse sequences and image contrast**
- T2, bright fluid
- T1 multi-phase
  - Pre-contrast 1W w/o fat suppression
  - Post-contrast 1W with fat suppression or subtraction (early and delayed phase)
- IV contrast must be evident in post-contrast images
- Must demonstrate sufficient SNR (not too grainy)
- Choice of acquisition parameters will determine scan time, SNR, resolution
Breast MR Image Quality

Category B: Positioning and Anatomic Coverage
- Adequate breast tissue in coil
- Proper positioning of breast tissue
- Full coverage from axillary tail to inframammary fold
- Absence or minimal skin folds
- Appropriate FOV

Category C: Artifacts
- Excessive artifacts can interfere with interpretation
- Some are unavoidable on certain images
- Some are due to pulse sequence errors, inadequate equipment, proper maintenance (PM, QC) of equipment

Breast MRI Artifacts

Common artifacts in breast MRI
- Motion
- Truncation artifacts
- Out of volume wrap
- Susceptibility artifacts
- Signal non-uniformity
- Poor or non-uniform fat saturation

Motion artifacts
Occur in the phase encoding direction. Caused by cardiac motion, respiration, patient movement. Results in phase mis-mapping in k-space due to the time delay between phase-encoding and signal readout.
**Truncation Artifacts**

- Occur at high contrast edges.
- Also known as Gibbs or “ringing” artifact.
- Can occur in either phase or frequency direction.
- Minimized by increasing matrix size
  - High contrast spatial resolution improves
  - Scan time also increases if phase matrix is increased
  - SNR reduced

**Aliasing or “Wrap-Around” Artifacts**

- Increase FOV to include entire object - increase phase-encode steps to maintain resolution (trade-off: impacts scan time)
- Swap phase and frequency-encoding directions - shorter dimension in phase-encoding direction. (trade-off: motion artifacts)
- Use “No phase wrap” or “anti-aliasing” techniques.

**Peripheral signal artifact**

*Signal originates in region where gradients are nonlinear. FID from 180 pulses not crushed - aliases back into image.*
Magnetic Susceptibility Artifacts
Metallic objects can cause distortions of the static and gradient fields, RF fields, or both
- Ferromagnetic objects - distort B₀ and B₁ fields
- Non-ferromagnetic metal objects - distort B₁ fields

Typical effects are signal voids and geometric distortions.

Most noticeable on GRE (rather than SE or FSE). Appearance reduced with wider receive BW, shorter TE.

Breast MR Image Quality

Category D: Spatial and Temporal Resolution
Determine from DICOM header

Spatial resolution – There are 5 determinants of voxel dimensions in an MRI examination:
1. Slice thickness (ST)
2. Field of view along the phase-encoding direction (FOVp)
3. Field of view along the frequency-encoding direction (FOVf)
4. Number of phase encoding steps (Np)
5. Number of frequency encoding steps (Nf)

Breast MR Image Quality

Spatial resolution

High contrast spatial resolution requires small voxels:
- Large matrix
- Small FOV
- Thin slices

\[ \text{High contrast resolution} \approx \frac{\text{FOV}}{N} \]

Trade-offs:
- Longer scan time if phase matrix is increased
- Reduced SNR \( \Rightarrow \) improve with 3T imaging

\[ \text{Spatial resolution in } \text{mm} = \frac{\text{FOV}}{N} \]

\[ \text{Spatial resolution in } \text{mm} = \frac{\text{FOV}}{N_p \text{ (phase encoding)}} \]

\[ \text{Spatial resolution in } \text{mm} = \frac{\text{FOV}}{N_f \text{ (frequency encoding)}} \]

\[ \text{Spatial resolution in } \text{mm} = \frac{\text{slice thickness}}{N_{\text{slice}}} \]

\[ \text{Acquisition time} = TR \times N_{\text{ave}} \times N_f \]

Breast MR Image Quality

Category D: Spatial and Temporal Resolution

- Spatial resolution for T1-weighted multi-phase series
  - Acquired (not interpolated) thickness must be \( \leq 3 \text{mm} \)
  - \( > 4 \text{mm} \) will fail.
  - 3–4mm: may fail if there are deficiencies in other categories.
  - In-plane resolution must be \( \leq 1 \text{mm} \) (phase and freq)
  - \( > 1.2 \text{mm} \) will fail
  - 1.0–1.2mm may fail if deficiencies in other categories.
  - Interslice gap must be \( \leq 0 \text{mm} \) (i.e. no gap)
  - \( > 0 \text{mm} \) will fail
Category D: Spatial and Temporal Resolution

- Temporal resolution – total time between contrast injection completion and end of early phase post-contrast T1 series: <=4 min, >5 min will fail, 1 min - 5 min may fail if other deficiencies
- Total time = time delay + acq time
- Example: 

Breast MR Image Quality

Basket E: Exam identification

- Information must be displayed or easily accessed through DICOM header on CD/DVD.
- Some viewers do not display laterality
- If laterality is absent or incorrect, case will fail

- Place labels on CD case, not CD. BMRAP ID#, CD#
**Shimming**

- Shim volume – user prescribes graphically
- Current in shim coils adjusted to optimize $B_0$ field uniformity within the volume. Improves uniformity of fat saturation.

**Clinical examples**

- Non-uniform signal
- Non-uniform fat suppression
- Motion/ghosting
- Work with med phys and/or equip manuf to correct deficiencies
- Result: pass

1.5T Sag T2 Right Breast: Biopsy proven carcinoma Unit 01

**Clinical examples**

- Low SNR
- Images too grainy
- Work with physicist and/or equipment manufacturer to correct deficiencies
- Result: pass

1.5T 3D Vibrant: BIRADS 1 or 2, Unit 01

**SAMS questions**

- Note – in final document questions will be interspersed throughout the presentation
The following equipment is required for ACR Breast MRI Accreditation

0% 1. MRI scanner of field strength 1.5 Tesla or greater
0% 2. RF coil capable of unilateral breast imaging
0% 3. Dedicated breast coil capable of simultaneous bilateral imaging
0% 4. Dedicated breast MRI scanner
0% 5. MRI-guided biopsy capabilities at the facility

Correct answer:
3. Dedicated breast coil capable of simultaneous bilateral imaging

Incorrect answers:
1. No requirement for minimum field strength.
2. Unilateral imaging not appropriate
4. Dedicated breast MRI scanner is not required. Scanner may be whole body with breast imaging coils/table.
5. MRI guided biopsy capability. Correlation with mammography, breast US, MRI-guided biopsy. If not available at the facility, create referral arrangement with a cooperating facility that does provide these services.


For facilities with more than one MRI scanner, which scanners must be accredited?

0% 1. MRI scanners dedicated to interventional procedures
0% 2. MRI scanners used for MRI-guided breast biopsy but not diagnostic breast imaging
0% 3. MRI scanners dedicated to radiation therapy treatment planning
0% 4. MRI scanners used for diagnostic breast MR imaging as well as whole body MR imaging
0% 5. All MRI scanners at the facility

Correct answer:
4. MRI scanners used for diagnostic breast MR imaging as well as whole body MR imaging

Incorrect answers:
1, 2, 3. Scanners used only for interventional procedures, MR-guided breast biopsy (but not diagnostic breast imaging), or for radiation therapy treatment planning do not need to be accredited for the facility to be BMRAP accredited.
5. All scanners at the facility do not need to be accredited. Only those performed diagnostic breast MR imaging.

What are the ACR accreditation requirements for the qualified medical physicist working in breast MRI?

0%  1. Must be board-certified
0%  2. Must perform the system performance evaluation at least annually
0%  3. Must be involved in the accreditation process
0%  4. Must review the clinical exams to be submitted to the ACR
0%  5. Must evaluate the breast MRI protocols for adequate spatial and temporal resolution

Correct answer:
2. Must perform the system performance evaluation at least annually

Incorrect answers:
1. Board certification is recommended, but not required.
3. It is recommended, but not required, that the physicist be involved in the BMRAP process.
4,5. The physicist can be helpful with clinical image review and assessment of spatial and temporal resolution, but it is not required.


The following test results must be included in the physicist’s Annual MRI System Performance Evaluation

0%  1. Magnetic field homogeneity test
0%  2. Repeat of technologist daily/weekly QC tests
0%  3. Tests of all RF coils used clinically including breast coils
0%  4. Review of technologist QC program
0%  5. All of the above

Correct answer:
5. All of the above

Incorrect answers:
None

The breast MRI cases submitted to the ACR for Breast MRI Accreditation

Correct answer:
2. Must include localizer, T2-W bright fluid series, and dynamic multi-phase T1-W series

Incorrect answers:
1. One BIRAD 6 case, biopsy-proven carcinoma, is submitted. BIRADS 1 or 2 cases are no longer required.
3. Cases must be less than 6 months old
4. Artifacts may be present, but not excessive, so as to not interfere with interpretation.
5. Slice thickness ≤ 3.0mm (not 5mm), in-plane pixel resolution ≤ 1.0mm (not 3mm), no gap


Signal non-uniformity in clinical breast MR images may be due to

Correct answer:
5. Any of the above

Incorrect answers:
1-2, 4. Adequate shimming, a correctly functioning coil, and good breast positioning are necessary for uniform signal intensity.
3. Uneven fat saturation will result in non-uniform signal.

References


