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

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
  AND
- 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.
**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)

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

**Continuing Education:**
- 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

**Initial qualifications:**
1. Board Certification in Radiological Physics or Diagnostic Radiological Physics (ABR), in MRI Physics (ABMP), or in Diagnostic Radiology 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

**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).
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.

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

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

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
Equipment Requirements

- 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

Breast RF Coil Quality Control

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

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

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
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) *No longer required*

Cases may not be older than 2 months

Exams must include these 4 sequences:

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2-Weighted/Bright Fluid Series</td>
<td>Adequate SNR, not too granry</td>
</tr>
<tr>
<td></td>
<td>Sufficient bright fluid contrast</td>
</tr>
<tr>
<td>Multi-Phase T1/Weighted Series:</td>
<td>Adequate SNR, not too granry</td>
</tr>
<tr>
<td>Pre-Contrast T1</td>
<td>Adequate SNR, not too granry</td>
</tr>
<tr>
<td>Early Phase (T1): Post-Contrast T1</td>
<td>Adequate SNR, not too granry</td>
</tr>
<tr>
<td>Delayed Phase (late): Post-Contrast T1</td>
<td>Adequate SNR, not too granry</td>
</tr>
<tr>
<td></td>
<td>Technical factors match pre-contrast T1</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Inter-Frame Gap</th>
<th>Maximum Recomended Pixel Size for Phase and Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 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.
Breast MR Image Quality

Challenges:
- Adequate SNR: *ACR: “not too grainy”*
- Good spatial resolution
  - \( \leq 1\text{mm} \times 1\text{mm} \) in-plane resolution
  - \( \leq 3\text{mm} \) 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

Breast MR Image Quality

3T – trade additional SNR for increased spatial resolution or faster scan time

1.5T

FSE T2W w/ fat sat,
FOV 220mm, 256x192, 4mm

3T

FSE T2W w/ fat sat,
FOV 200mm, 320x192, 3mm

3.0T

FSE T2W w/ fat sat,
FOV 200mm, 320x192, 3mm

Category A: pulse sequences and image contrast
- T2, bright fluid
- T1 multi-phase
  - Pre-contrast T1W w/ or w/o fat suppression
  - Post-contrast T1W with fat suppression or subtraction (early and delayed phases)
  - IV contrast must be evident in post-contrast images
- Must demonstrate sufficient SNR (not too grainy)
- Choice of acq params will determine time, SNR, resol
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 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 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**
(FSE: Star artifact – bright signal close to center of images.
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)

Spatial resolution

\[ \delta_{\text{slice}} = \frac{\text{FOV}_s}{N_s} \]
\[ \delta_{\text{phase}} = \frac{\text{FOV}_p}{N_p} \]
\[ \delta_{\text{frequency}} = \frac{\text{FOV}_f}{N_f} \]

Category D: Spatial and Temporal Resolution

- Spatial resolution for T₁-weighted multi-phase series
- Acquired (not interpolated) thickness must be \( \leq 3\text{mm} \)
- \( > 4.0\text{mm} \) will fail.
- \( 3\text{-}4\text{mm} \): 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)
- \( > 0 \) will fail

Spatial resolution

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

Trade-offs:
- Longer scan time if phase matrix is increased
- Reduced SNR \( \Rightarrow \) improve with 3T imaging
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
- Example: ….
- Total time = time delay + acq time

Category E: Exam identification

- Information must be displayed or easily accessed through DICOM header on CD/DVD.
- Some viewers do not display laterality
  - Patient’s first and last names
  - Patient age or date of birth
  - Patient identification number
  - Facility name
  - Examination date
  - Laterality, left or right of radiate section, interslice gap
- Place labels on CD case, not CD. BMRAP ID#, CD#

Frequency selective fat sat

- Frequency-selective fat or silicone saturation is routinely used in breast imaging. Frequency of saturation pulse must match resonant frequency of fat/silicone.
- Selection of resonant peak usually automated, but may require manual adjustment → Technologist training essential.
- Uniform saturation dependent on homogeneity of B0 field within the imaged volume:
  - challenge (breasts off isocenter)
  - shimming is important
Shimming

- Shim volume – user prescribes graphically
- Current in shim coils adjusted to optimize B₀ 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

Clinical examples

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

SAMS questions

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

- MRI scanner of field strength 1.5 Tesla or greater
- RF coil capable of unilateral breast imaging
- Dedicated breast coil capable of simultaneous bilateral imaging
- Dedicated breast MRI scanner
- MRI-guided biopsy capabilities at the facility

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

- MRI scanners dedicated to interventional procedures
- MRI scanners used for MRI-guided breast biopsy but not diagnostic breast imaging
- MRI scanners dedicated to radiation therapy treatment planning
- MRI scanners used for diagnostic breast imaging as well as whole body imaging
- All MRI scanners at the facility
What are the ACR accreditation requirements for the qualified medical physicist working in breast MRI?

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

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

1. Magnetic field homogeneity test
2. Repeat of technologist daily/weekly QC tests
3. Tests of all RF coils used clinically including breast coils
4. Review of technologist QC program
5. All of the above
### The breast MRI cases submitted to the ACR for Breast MRI Accreditation

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>1. Must be BIRADS category 1 or 2</td>
</tr>
<tr>
<td>0%</td>
<td>2. Must include localizer, T2-W bright fluid series, and dynamic multi-phase T1-W series</td>
</tr>
<tr>
<td>0%</td>
<td>3. Can be more than one year old</td>
</tr>
<tr>
<td>0%</td>
<td>4. Must be completely free of artifacts</td>
</tr>
<tr>
<td></td>
<td>5. Acquired slice thickness ≤ 5.0mm, in-plane pixel resolution ≤ 3.0mm, no gap</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>1. B₀ field inhomogeneity due to inadequate shimming</td>
</tr>
<tr>
<td>0%</td>
<td>2. Coil element failure</td>
</tr>
<tr>
<td>0%</td>
<td>3. Uneven fat suppression</td>
</tr>
<tr>
<td>0%</td>
<td>4. Poor breast positioning within the coil</td>
</tr>
<tr>
<td></td>
<td>5. Any of the above</td>
</tr>
</tbody>
</table>
References