ACR Breast MRI Accreditation Program - DRAFT

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Making Cancer History®

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

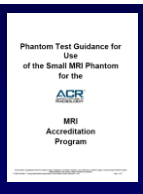
Breast MRI RF Coils

Guidance documents

www.acr.org

Breast Magnetic Resonance Imaging (MRI) Accreditation Program Requirements

ACR AMERICAN COLLEGE OF RADIOLOGY



Accreditation fees

Accreditation Fees

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

Cycle	Fees
Accreditation *(Initial cycle and renewal)*	**$2,400** for the first unit **$2,300** each additional unit at the same geographic location
Repeat	**$700** for each unit
Reinstate/Corrective Action Plan	**$2,400** for the first unit **$2,300** each additional unit at the same geographic location
Add units *(mid cycle)*	**$1,400** for each unit
Replacement Certificate	**$65** per certificate

www.acr.org Breast MRI Accreditation Program Requirements, 5/10/2010

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 – 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 ro 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
3. Grandfathered: Surveys of at least 3 MRI units between January 1, 2007 and January 1, 2010.

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).

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.

www.acr.org Breast MRI Accreditation Program Requirements, 5/10/2010

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

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

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 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

BMRAP Clinical Images

Exams must include these 4 sequences:

Sequence	Criteria
T2-Weighted/Bright Fluid Series	• Adequate SNR/not too grainy • Sufficient bright fluid contrast
Multi-Phase T1-Weighted Series:	
Pre-Contrast T1	• Adequate SNR/not too grainy
Early Phase (first) Post-Contrast T1	• Adequate SNR/not too grainy • Completed within 4 minutes of completion of injection • Technical factors match pre-contrast T1
Delayed Phase (last) Post-Contrast T1	• Adequate SNR/not too grainy • Technical factors match pre-contrast T1

www.acr.org Breast MRI Accreditation Program Requirements, 5/10/2010

BMRAP Clinical Images

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

Sequence	Slice Thickness	Gap	Maximum Recommended In Plane Pixel Dimension for Phase and Frequency
Sagittal, Axial and/or Coronal	≤3 mm	0 mm	≤1 mm

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.

Clinical Image Review Categories
1. Pulse sequences and image contrast
2. Positioning and anatomic coverage
3. Artifacts
4. Spatial and temporal resolution
5. Exam identification

www.acr.org Breast MRI Accreditation Program Requirements, 5/10/2010

Breast MR Image Quality

Challenges:

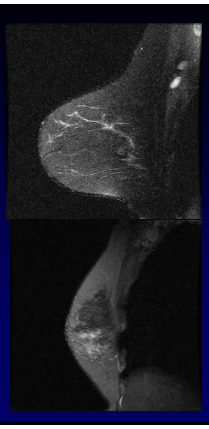
- Adequate SNR *ACR: "not too grainy"*
- Good spatial resolution
  - ≤ 1mm x 1mm in-plane resolution
  - ≤ 3mm slice thickness
- Temporal resolution dynamic series (60-90 sec/phase)
- Absence of (or minimal) artifacts
- Effective, uniform fat suppression

SNR

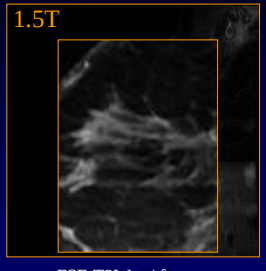
Potential causes of low SNR:

- 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

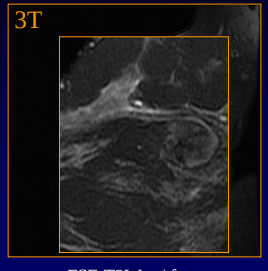
$$SNR \propto \rho_{1_H} \frac{FOV_v \; FOV_\phi}{\sqrt{N_v \; N_\phi \; \Delta\upsilon_{samp}}} \; \delta_s \; \sqrt{N_{ave}} \; B_0 \; f$$



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



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



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

Breast MR Image Quality

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

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

Breast MR Image Quality

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

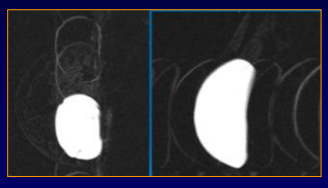
Breast MRI Artifacts

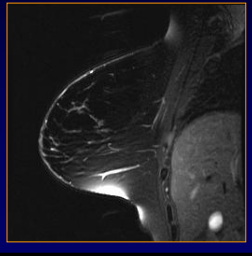
Common artifacts in breast MRI

- 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.





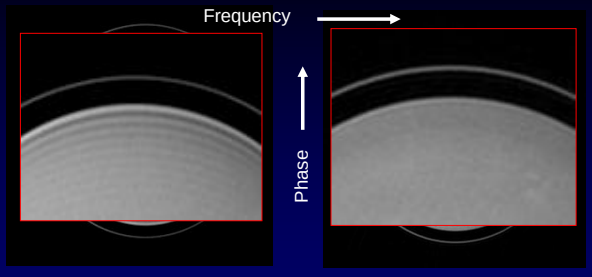
Truncation Artifacts

- 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

Object profile

Measured intensity profile

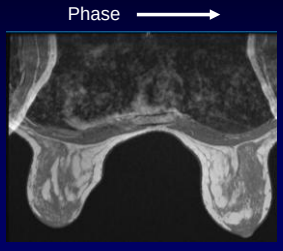
Truncation Artifacts



Small ACR phantom in 3T GE HD Breast array

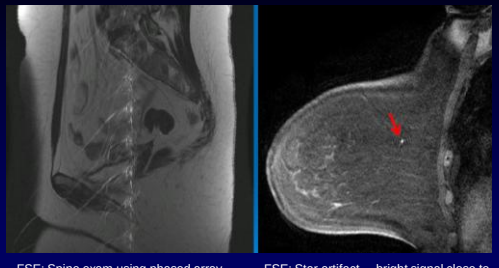
320x192 matrix 320x320 matrix

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 (annefact, star artifact)



FSE: Spine exam using phased array surface coil .

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.

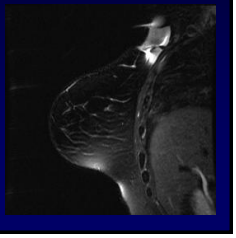
Magnetic Susceptibility Artifacts

Metallic objects can cause distortions of the static and gradient fields, RF fields, or both

- Ferromagnetic objects - distort B_0 and B_1 fields
- Non-ferromagnetic metal objects - distort B_1 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)

Pixel Size and Voxel Volume Calculations
In-plane pixel size (phase) = (FOV_p/N_p)
In-plane pixel size (frequency) = (FOV_f/N_f)
Pixel area = $(FOV_p/N_p) \times (FOV_f/N_f)$
Voxel volume = (Pixel area) x (ST)

Spatial resolution

High contrast spatial resolution requires small voxels:

- Large matrix
- Small FOV
- Thin slices

$\delta_{fr} = FOV_{fr} / N_{fr}$	Resolution (frequency-encoding direction
$\delta_{ph} = FOV_{ph} / N_{ph}$	Resolution (phase encoding direction)
δ_{slice}	Resolution (slice direction)

Trade-offs:

- Longer scan time if phase matrix is increased

$T_{scan} = TR \cdot N_{ave} \cdot N_{ph}$ Acquisition time

- Reduced SNR → improve with 3T imaging

Breast MR Image Quality

Category D: Spatial and Temporal Resolution

- Spatial resolution for T1-weighted multi-phase series
- Acquired (not interpolated) thickness must be <=3mm
- > 4.0mm will fail.
- 3-4mm: may fail if there are deficiencies in other categories.
- In-plane resolution must be <=1mm (phase and freq)
- >1.2mm will fail
- 1.0-1.2mm may fail if deficiencies in other categories.
- Interslice gap must be <= 0mm (i.e. no gap)
- >0 will fail

Breast MR Image Quality

Category D: Spatial and Temporal Resolution

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

Breast MR Image Quality

Category 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, the case will fail accreditation.

- Patient's first and last names
- Patient age or date of birth
- Patient identification number
- Facility name
- Examination date
- Laterality, left or right of midline section Interslice gap

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

ACR Clinical Image Evaluation Criteria Summary

Facilities not submitting the required sequences or submitting cases that do not meet the following criteria will fail accreditation.

Required Sequences	Image Quality Criteria		
	Category A: Pulse Sequences and Image Contrast	Category B: Positioning and Anatomic Coverage	Category D: Spatial and Temporal Resolution
T2-Weighted/ Bright Fluid Series	• Adequate SNR/not too grainy • Sufficient bright fluid contrast	• Adequate breast tissue inside coil • Breast properly positioned within coil • Properly positioned nipple • Image set covers both breasts, from axillary tails to inframammary folds • Minimal or no skin folds	NA
Pre-Contrast T1	• Adequate SNR/not too grainy		• Slice Thickness ≤3 mm • Gap ≤0 mm • In-plane pixel (phase) ≤1 mm • In-plane pixel (frequency) ≤1 mm • Early phase post-contrast T1-weighted series completed within 4 minutes of completion of injection
Early Phase Post-Contrast T1	• Adequate SNR/not too grainy • If fat suppression is not evident, subtracted images also must be provided		
Delayed Phase Post-Contrast T1	• Technical factors match pre-contrast T1 • IV contrast is evident		

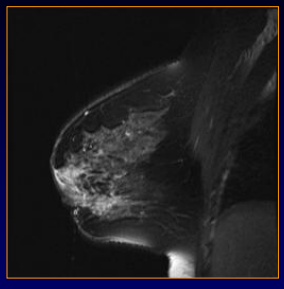
Frequency selective fat sat

- 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 B_0 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 B_0 field uniformity within the volume. Improves uniformity of fat saturation.

Clinical examples



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

T2W fast spin-echo
TR =4367ms / TE_{eff} =81 ms
echo train length = 17
122 Hz/pixel bandwidth
256x192 matrix, 220 mm FOV
4mm thickness/ 0mm gap
2 averages
fat sat

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

Clinical examples

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

3D Vibrant Dynamic
TR =4.8 ms / TE =2.3 ms
Flip angle 10°
390.6 Hz/pixel bandwidth
256x256 matrix, 180 mm FOV
2.4mm thickness/ 1.2 spacing
0.5 NEX
fat sat

- 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

0% 1. MRI scanner of field strength 1.5 Tesla or greate
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

10

Discussion slide – answer to SAMs question
Reference

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 biopsi but not diagnostic breast imaging
0% 3. MRI scanners dedicated to radiation therapy treatment planning
0% 4. MRI scanners used for diagnostic breast imaging well as whole body imaging
0% 5. All MRI scanners at the facility

10

Discussion slide – answer to SAMs question
Reference

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 least annually
0% 3. Must be involved in the accreditation process
0% 4. Must review the clinical exams to be submitted t the ACR
0% 5. Must evaluate the breast MRI protocols for adequate spatial and temporal resolution

10

Discussion slide – answer to SAMs question
Reference

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 bre coils
0% 4. Review of technologist QC program
0% 5. All of the above

10

Discussion slide – answer to SAMs question
Reference

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

0%
0%
0%
0%
0%

1. Must be BIRADS category 1 or 2
2. Must include localizer, T2-W bright fluid series, and dynamic multi-phase T1-W series
3. Can be more than one year old
4. Must be completely free of artifacts
5. Acquired slice thickness ≤ 5.0mm, in-plane pixel resolution ≤3.0mm, no gap

10

Discussion slide – answer to SAMs question
Reference

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

0%
0%
0%
0%
0%

1. B_0 field inhomogeneity due to inadequate shimming
2. Coil element failure
3. Uneven fat suppression
4. Poor breast positioning within the coil
5. Any of the above

10

Discussion slide – answer to SAMs question
Reference

References

1. Breast MRI Accreditation Program Requirements, 11/22/2011. www.acr.org
2. BMRAP Clinical Imaging Quality Guide, 9/23/2011. www.acr.org
3. ACR Magnetic Resonance Imaging (MRI) Quality Control Manual, 2004. (under revision)
4. ACR Technical Standards for Diagnostic Medical Physics Performance Monitoring of MRI Equipment, revision 2009. www.acr.org
5. Jackson EF, Bronskill MJ, Drost DJ, et al. Acceptance testing and quality control for magnetic resonance imaging facilities: report of AAPM MR Subcommittee Task Group