Breast MRI Clinical Scanning Procedural Guidelines

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Purpose: These procedural guidelines are designed to provide the MRI operator with the necessary guidance to perform the examinations described within. They are reviewed at minimum annually so as to maintain currency.

In addition to the scanning parameters and guidance in this document, specifications from the ACR Breast MRI Accreditation program are also included for reference purposes and to support the compliance of these protocols with the ACR Accreditation program. Please do not confuse this additional support information with the actual protocol guidance itself. The protocols within are specifically designed and monitored to assure compliance with ACR accreditation and also to provide the image quality and resolution required by our breast radiologists.

American College of Radiology Breast MR Imaging Guidelines

The information below is excerpted directly from the ACR website on Breast MRI Accreditation and is provided here as a convenience to help sites achieve the level of exam and image quality expected by the ACR. Current versions may be reviewed here: https://accreditationsupport.acr.org/support/solutions/articles/11000063266-complete-accreditation-information-breast-mri

Submission Requirements

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

Positioning

Proper breast positioning and anatomic coverage are important components of breast MRI exams. The field-of-view (FOV) and breast coverage must be adequate for accurate diagnosis of breast cancer. Specific image acquisition planes are not specified and are left to the discretion of the facility. The following aspects of positioning will be evaluated:

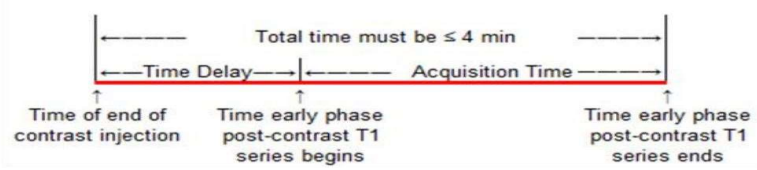
-Adequate breast tissue inside the coil
-Proper positioning of the breast within the coil
-Properly positioned nipple
-Coverage of the entire breast, from the axillary tail to the inframammary fold
-Absence or minimization of skin folds
-Appropriate FOV

Spatial Resolution

The Breast MRI Accreditation Program's requirements for spatial resolution for the T1-weighted multi-phase series are as follows:
-The acquired (not interpolated) slice thickness must be ≤ 3.0 mm. Cases with slice thicknesses > 4.0 mm will fail; cases with slice thicknesses > 3.0 but ≤ 4.0 mm may fail if the reviewers note deficiencies in other categories.
-The in-plane pixel resolution must be ≤ 1.0 mm (for both phase and frequency). Cases with in-plane pixel resolution > 1.2 mm will fail; cases with in-plane pixel resolution > 1.0 but ≤ 1.2 mm may fail if the reviewers note deficiencies in other categories (e.g. poor positioning, significant artifacts, etc.).
-The interslice gap must be ≤ 0 mm. Cases with gaps > 0 mm will fail.

Temporal Resolution

The first post-contrast sequence must have been completed in ≤ 4.0 minutes of completion of contrast injection. Cases with a total time > 5.0 min will fail; cases with a total time > 1.0 but ≤ 5.0 min may fail if the reviewers note deficiencies in other categories.



Artifacts

Common Breast MRI Artifacts	
Motion/ghosting	Appear as periodic replication or partial replications of bright structures along the phase-encoding direction and could be due to patient motion, fluid pulsation including cardiac or vascular pulsation, unstable gradients, or other causes.
Non-uniform/ heterogeneous fat suppression	Appear as uneven darkening of the fat signal in different portions of the image set and may be due to either a heterogeneous magnetic field or a heterogeneous radiofrequency (RF) field.
Aliasing/wrap artifacts	The image appears wrapped around onto itself. This is due to signal-producing tissue outside the selected FOV wrapping back into the displayed FOV on the opposite side of the image. If image wrap occurs, it is usually along the phase-encoding direction. Increasing the FOV or applying phase oversampling are the two most effective ways of eliminating or minimizing wrap artifacts.
Truncation/ ringing artifacts (edge ringing)	Appear as periodic parallel lines or ringing adjacent to borders or tissue discontinuities, in either the phase-encoding or frequency-encoding directions. This is due to selection of too small a matrix in one or both in-plane directions, occurring most commonly in the phase-encoding direction.
Non-uniform/ heterogeneous signal within breasts	This is due to RF heterogeneity, receiver coil non-uniformities, non-functioning coil elements, improper patient positioning, or metal in the magnet or on the patient.
Susceptibility	Appear as localized field distortion or non-uniformities produced by differing tissue magnetic susceptibilities (especially at air-tissue interfaces).
Chemical shift	Occurs along the frequency-encoding direction at fat/water soft tissue interfaces as a thin intense band of high or low signal.
Geometric distortion	Occurs when size, orientation or shape is not accurately represented on the image.
Filtering	Occurs when excessive software smoothing is used to reduce apparent noise in the image. Excessive filtering or smoothing obscures true anatomical structure through image blur and can reduce image contrast.
RF leak (zipper artifact)	Appear as linear hyperintense or variable intensity lines parallel to the phase-encoding direction, often caused by unwanted sources of RF signals originating within (e.g., light bulbs or other electronic equipment) or outside the scanner room (e.g., RF signals penetrating the scan room because the door is open, the RF seal between the door and frame is damaged, or RF shielding is inadequate).
Misregistration of subtracted images	On subtracted images, incomplete subtraction of background tissue signals occurs because pre- and post-contrast images do not register properly, usually due to patient motion.

Scan Series Specifications

Specifications for the T2-weighted/bright fluid series:
-May be run as a single series on both breasts or as 2 separate series, 1 on each breast. In the latter case, 2 separate series numbers and data should be entered in the Test Image Data form under "T2-Weighted Bright Fluid Series" so the reviewers will know that you did both breasts with a T2-weighted series. You do not need to bind them into a single series.

Specifications for the multi-phase T1-weighted series:
The intent of early phase and delayed phase post-contrast imaging is to capture information on lesion enhancement in the early and late phases of post-contrast enhancement.
-Must be run bilaterally, with both the left and right breasts in the same series.
May be in 3 separate series, in 2 series (i.e., 1 for pre-contrast, the rest for post-contrast), or in a single series (i.e., pre-contrast and post-contrast).
-All 3 multi-phase series should match in terms of spatial and temporal parameters. Some small deviations may exist in the parameters listed in the series DICOM header files (e.g., in TR and TE values) between the pre- and post-contrast series. As long as these differences are small and do not affect the ability to subtract pre- from post-contrast series, such small differences are acceptable.

Pulse Sequences and Image Contrast

The selection of appropriate pulse sequences is critical. They are the major determinant of image contrast and thus determine the appearance of both normal tissues and breast pathology. In order to depict and characterize abnormalities, a comprehensive breast MRI exam should include pulse sequences that provide more than one type of image contrast. The specific type of pulse sequences (e.g., conventional SE, fast SE, turbo SE, gradient-echo) and the precise imaging parameters (e.g., TR, TE, flip angle, echo train length) are not specified and are left to the discretion of the imaging facility.

T2-Weighted/Bright Fluid Series

-Term used to indicate an image where most of the contrast between tissues or disease states is due to differences in the tissue T2 (or T2*), with fluid such as blood or cystic fluid appearing bright. The term "T2-weighted" may be misleading in that spin density differences and T1 differences also may contribute to image contrast. The T2-weighted/bright fluid sequence should demonstrate fluid as sufficiently bright to be considered a true bright fluid sequence. The case will fail if bright fluid is absent or indistinguishable from background tissues, such that the deficit could lead to misdiagnosis or is inadequate to reliably distinguish cysts from solid masses. If the bright fluid contrast is present, but is faint or highly variable, the case could fail if other image problems exist.

-An Ax T2 fat-sat sequence is desirable. With a T2 fat-sat (or STIR) the fat is suppressed (i.e., becomes dark) and the bright fluid is much easier to see.

-A Short TI Inversion Recovery (STIR) image with TI set to suppress fat signal may be considered a T2-weighted/bright fluid series if it successfully shows fluid to be bright. A T2*-weighted or a non-spoiled (steady state) T1-weighted gradient echo pulse sequence also may be satisfactory as a bright fluid sequence if it shows fluid as being adequately bright (i.e., brighter than all other tissues in the breast).

The Committee on Breast MRI Accreditation has determined that contrast should generally not appear in a good quality T2-weighted bright fluid series. Also, the vast majority of exams performed at US facilities do T2W imaging before, rather than after, administration of the contrast agent. The reason that you would not want to do T2W imaging after contrast administration is that the basis for bright fluid in T2W imaging is the longer T2 of fluid, cystic or vascular, compared to cellular tissue. Administering contrast agent shortens the T2 values of perfused fluids and tissues, particularly vessels, so contrast agent decreases the brighter T2W appearance of the vascular bed. It would not necessarily affect cysts. If there are no cysts in the breasts, the only way ACR reviewers can evaluate the presence of bright fluid contrast in T2W images is to see bright vessels. The addition of contrast agent during T2W imaging is likely to decrease their visibility and could compromise bright fluid evaluation.

Multi-Phase T1-Weighted Series

-Pre-contrast T1-weighted without or with fat suppression: Term used to indicate an image where most of the contrast between tissues and disease states is due to differences in T1. A T1-weighted image is achieved by imaging with a short TR relative to the longest tissue T1 of interest and a short TE relative to the tissue T2 (to reduce T2 contributions to image contrast). Short TR/short TE sequences are a necessary component of the required examination. This sequence must have sufficient dark fluid contrast to be considered a true T1-weighted sequence. Fat suppression may be used for this sequence, along with the post-contrast series that follow. If fat suppression is not used, subtraction images with these pre-contrast images subtracted from post-contrast images must be reconstructed and submitted.

-Post-contrast T1-weighted with fat suppression or subtraction (early and delayed phases): The intent of early phase and delayed phase post-contrast imaging is to capture information on lesion enhancement in the early and late phases of postcontrast enhancement. These pulse sequences must be identical to the pre-contrast T1-weighted series described above in terms of spatial and temporal parameters. There are 2 acceptable exceptions to this requirement:

-Small deviations between pre- and post-contrast series may appear in the DICOM header files of some series, even though identical acquisition parameters were selected

-If fat suppression is used for the pre-contrast T1, it should also be used for this sequence. If fat suppression is not used, subtraction images with pre-contrast images subtracted from these post-contrast images must be reconstructed and submitted, along with the un-subtracted source post-contrast T1-weighted images. At least 2 phases of post-contrast images must be submitted: the earliest and the latest phase post-contrast series.

-All sequences must demonstrate sufficient signal to noise (SNR) and not appear too grainy. The details of the pulse sequence, along with other selected parameters such as imaging matrix and number of signal acquisitions (per phase-encoding step) acquired, will determine the image acquisition time and SNR. In general, short acquisition times are desirable to limit patient motion and discomfort and provide flexibility such that additional sequences may be obtained if desired; however, short acquisition times should not be employed if they can only be obtained at the expense of overall image quality and diagnostic value.

-IV contrast must be evident in the 2 post-contrast T1-weighted series. Please see the documents on MR Contrast Agents and Contrast Media at the ACR's Radiology Safety webpage for contrast safety information.

Timing of the scan phases and coordination of the injection at the expected flow rate is critical to maintain the integrity and diagnostic value of the kinetic information obtained during the dynamic scan.

- It is expected that the flow rate for breast studies will be 2.0ml/sec across the board with a minimum volume of 10ml (adjustment required for Gadavist).
- Scan time *per phase* for the dynamic scans should be 3:00 +/- 10 sec.
- The first phase of the dynamic series should be started at the same time or delayed by no more than 10 seconds unless the flow rate is reduced.
- If there is a need to decrease the flow rate, a compensatory delay must be introduced between the start of the injection and the start of the dynamic post contrast scan.
  - A simple formula is to determine the expected injection duration at 2.0ml/sec, and then the adjusted injection duration at the new flow rate. Subtract the duration at 2.0ml/sec from the duration at the new flow rate and use the resulting number as a pre-scan delay for the dynamic series. (V/x)-(V/2)=D
  - For example if the volume is 18ml, the duration at 2.0ml/sec will be 9 sec; at 1.5ml/sec, the duration will be 12 sec. 12-9=3. Add a 3 second delay before starting the dynamic scan (pre-scan delay, not inject delay).

Any time that the flow rate is reduced, notes MUST be put in for the rad.

PROTOCOL: MRI BREAST ROUTINE-USED FOR NO IMPLANTS OR SALINE IMPLANTS *ONLY*

REVISION DATE: SEPTEMBER 2022

SLOT TIME: 45-60

CLINICAL INDICATIONS/ HISTORY BREAST MASS OR LUMP/BX PROVEN NEW DX OF BREAST CA/HIGH RISK SCREENING

CPT CODE

SCAN ORDER	PLANE	IMAGE CONTRAST/ WEIGHTING	MODE	PULSE SEQ	COVERAGE	TR RANGE	TE RANGE	TI	FLIP ANGLE	THICKNESS/GAP (mm)	FOV (cm)	Max Pixel (mm) x Ph Fr	PHASE AXIS	SEND TO PACS	Max scan time (target)
1	AX	STIR	2D	FSE	MUST COVER ALL BREAST TISSUE AS DESCRIBED BY THE ACR IN THEIR IMAGE QUALITY GUIDELINES	<9000	60-80	140-160	>130	4/5/2000	28-42	1.2 X 1.2	RL	FULL SERIES	5:00
2	AX	T1 (IN PHASE)	3D	FSPGR/ VIBRANT/ FLASH		MIN	IN PHASE	-	8-15	1.4-2.0/0vlp 1.6 is ideal Make sure all AX T1 series copy thickness and spacing from series 2	28-42	1.0 X 1.0	RL	FULL SERIES	2:45
3 (needed for GE)	AX	T1 FS (SHIMCHECK)	3D	VIBRANT/VIBE		MIN	MIN	-	8-15		28-42	1.0 X 1.0	RL	NO	3:00
4-5+C-6+C-7+C	AX	T1 FS DYNAMIC 4 Phase	3D	VIBRANT/VIBE		MIN	MIN	-	8-15		28-42	1.0 X 1.0	RL	FULL SERIES	3:00/ PHASE

PROTOCOL: MRI BREAST SILICONE-USED FOR SILICONE IMPLANTS *ONLY*

REVISION DATE: SEPTEMBER 2022

SLOT TIME: 60-75

CLINICAL INDICATIONS/ HISTORY BREAST MASS OR LUMP/BX PROVEN NEW DX OF BREAST CA/HIGH RISK SCREENING IN PATIENTS WITH SILICONE OR DUAL LUMEN (IN WHICH SILICONE IS PRESENT) IMPLANTS

CPT CODE

SCAN ORDER	PLANE	IMAGE CONTRAST/ WEIGHTING	MODE	PULSE SEQ	COVERAGE	TR RANGE	TE RANGE	TI	FLIP ANGLE	THICKNESS/GAP (mm)	FOV (cm)	Max Pixel (mm) Fr x Ph	PHASE AXIS	SEND TO PACS	Max scan time (target)
1	AX	STIR	2D	FSE	MUST COVER ALL BREAST TISSUE AS DESCRIBED BY THE ACR IN THEIR IMAGE QUALITY GUIDELINES	<9000	60-80	140-160	>130	4-5/0	28-42	1.2 X 1.2	RL	FULL SERIES	5:00
2	AX	T1 (IN PHASE)	3D	FSPGR/ VIBRANT/ FLASH		MIN	IN PHASE	-	8-15	1.4-2.0/0vlp 1.6 is ideal Make sure all AX T1 series copy thickness and spacing from series 2	28-42	1.0 X 1.0	RL	FULL SERIES	2:45
3 (needed for GE)	AX	T1 FS (SHIMCHECK)	3D	VIBRANT/VIBE		MIN	MIN	-	8-15		28-42	1.0 X 1.0	RL	NO	3:00
4-5+C-6+C-7+C	AX	T1 FS DYNAMIC 4 Phase	3D	VIBRANT/VIBE		MIN	MIN	-	8-15		28-42	1.0 X 1.0	RL	FULL SERIES	3:00/ PHASE
8-9	SAG: EACH BREAST SEPARATELY	WATER-SUPPRESSED STIR	2D	FSE	COVER FROM MIDLINE TO AXILLA	3000-7000	50-60	150	>130	4/0	20-24	1.0X1.0	HF	FULL SERIES	3:45
10	AX	T2	2D	FSE	SAME COVERAGE AS SERIES 1	4000-8000	150-200	-	>130	4-5/0	28-42	.8 X 1.2	RL	FULL SERIES	4:00

PROTOCOL: MRI BREAST DIXON-USED FOR PATIENTS WITH NO IMPLANTS *ONLY*

REVISION DATE: MARCH 2024

SLOT TIME: 45-60

CLINICAL INDICATIONS/ HISTORY BREAST MASS OR LUMP/BX PROVEN NEW DX OF BREAST CA/HIGH RISK SCREENING (THIS MAY BE USED IF FAT SUPPRESSION CANNOT BE OBTAINED USING SPECTRAL FAT SATURATION BUT *MUST* BE DISCUSSED WITH THE RADIOLOGIST *BEFORE* USING)

CPT CODE

SCAN ORDER	PLANE	IMAGE CONTRAST/ WEIGHTING	MODE	PULSE SEQ	COVERAGE	TR RANGE	TE RANGE	TI	FLIP ANGLE	THICKNESS/GAP (mm)	FOV (cm)	Max Pixel (mm) Fr x Ph	PHASE AXIS	SEND TO PACS	Max scan time (target)
1	AX	STIR	2D	FSE	MUST COVER ALL BREAST TISSUE AS DESCRIBED BY THE ACR IN THEIR IMAGE QUALITY GUIDELINES	<9000	60-80	140-160	>130	4/5/2000	28-42	1.2 X 1.2	RL	FULL SERIES	5:00
2	AX	T1 (IN PHASE)	3D	FSPGR/ VIBRANT/ FLASH		MIN	IN PHASE	-	8-15	1.4-2.0/0vlp 1.6 is ideal Make sure all AX T1 series copy thickness and spacing from series 2	28-42	1.0 X 1.0	RL	FULL SERIES	2:45
4, 5+C, 6+C, 7+C	AX	T1 FS DYNAMIC 4 Phase (1 PRE+3 POST)	3D	VIBRANT FLEX/VIBE DIXON		MIN	MIN	-	8-15		28-42	1.0 X 1.0	RL	FULL SERIES	3:00/ PHASE

PROTOCOL: MRI BREAST WO-SILICONE IMPLANT INTEGRITY

REVISION DATE: SEPTEMBER 2022

SLOT TIME: 60-75

CLINICAL INDICATIONS/ HISTORY EVALUATE EXISTING RUPTURE OR EVALUATE FOR SILICONE IMPLANT RUPTURE

CPT CODE

SCAN ORDER	PLANE	IMAGE CONTRAST/ WEIGHTING	MODE	PULSE SEQ	COVERAGE	TR RANGE	TE RANGE	TI	FLIP ANGLE	THICKNESS/ GAP (mm)	FOV (cm)	Max Pixel (mm) Fr x Ph	PHASE AXIS	SEND TO PACS	Max scan time (target)
1	AX	STIR	2D	FSE	MUST COVER ALL BREAST TISSUE AND IMPLANT	<9000	60-80	140-160	>130	4/0	28-42	1.0 X 1.2	RL	FULL SERIES	5:00
2	COR	T1	2D	FSE		MIN	<799	-	8-15		32-48	.8 X 1.2	RL	FULL SERIES	4:45
3	AX	T2	2D	FSE		4000-8000	150-200	-	>130		28-42	.8 X 1.2	RL	FULL SERIES	4:00
4-5	SAG: EACH BREAST SEPARATELY	WATER-SUPPRESSED STIR	2D	FSE	COVER FROM MIDLINE TO AXILLA	3000-7000	50-60	150	>130		20-24	1.0X1.0	HF	FULL SERIES	3:45