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Artifacts in Breast Magnetic Resonance Imaging

Marina-Portia Anthony, MBBS, BSc(Med), MPH, FRANZCR*, Dustin Nguyen, DO, Lauren Friedlander, MD, Victoria Mango, MD, Ralph Wynn, MD, FACR, Richard Ha, MD

Department of Radiology, Columbia University Medical Center, New York Presbyterian Hospital, New York, NY

As breast magnetic resonance imaging has evolved to become a routine part of clinical practice, so too has the need for radiologists to be aware of its potential pitfalls and limitations. Unique challenges arise in the identification and remedy of artifacts in breast magnetic resonance imaging, and it is important that radiologists and technicians work together to optimize protocols and monitor examinations such that these may be minimized or avoided entirely. This article presents patient-related and technical artifacts that may give rise to reduced image quality and ways to recognize and reduce them.
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Introduction

Breast magnetic resonance imaging (MRI) has become an important tool for high-risk screening, breast cancer staging, cancer treatment response, posttreatment evaluation for recurrence, and implant evaluation.[1-3] Unique challenges arise in breast MRI, and optimized imaging protocols and well-trained breast MRI technologists[1] are critical for providing high-quality diagnostic images.

Despite the tailored approach to breast MRI, problems still arise because of many factors such as nonuniform magnetic field and patient motion. These factors may manifest as artifacts in the acquired images and degrade image quality. An artifact is typically defined as any feature in an image or sequence that misrepresents the object in the field of view (FOV).[4] Artifact manifestations include additional unexpected signal on the image or sequence, a lack of signal, image distortion, and ghosting. The effect of the artifact on diagnostic assessment can vary from negligible to severe, in some instances potentially rendering an image or study nondiagnostic.

Artifacts in breast MRI are attributable to a variety of causes and may be grouped under 2 broad categories: patient-related artifacts (ie, positioning, motion, and susceptibility) and technical artifacts (ie, radiofrequency [RF] interference or zipper artifact, wrap-around, Moiré fringes or zebra stripes, chemical shift, and misregistration). It is critical for a radiologist to know the various breast MRI artifacts and to understand their causes to minimize potential negative effects on image interpretation and to fix them. This not only improves image quality but also reduces imaging time, which can improve both workflow and patient experience.

The American College of Radiology[1] provides practice parameters for the performance of contrast-enhanced MRI of the breast and accreditation guidelines, which are most useful for quality assurance in this area.

Breast MRI Protocol

A 1.5-T (or higher) strength magnet provides excellent signal for breast imaging,[5] with 3 T offering signal-to-noise ratio (SNR) advantages and also some technical challenges.[6] The examination is performed using a dedicated breast coil,[1] being a specialized surface coil with 2 elements, one for each breast, with the patient positioned prone. The breast coil must be plugged in and selected by the technologist. Feet-first entry into the gantry may help prevent claustrophobia. Gadolinium-based contrast material is used for all examinations except those tailored exclusively for implant assessment, administered intravenously at a dose of 0.1 mmoL/kg at a rate of 1.2 mL/s with a 10-mL flush of saline.

Unique technical challenges arise in breast MRI because of the necessary large FOV to image both the breasts, as well as requirements for homogeneous fat suppression, high spatial resolution, uniform signal intensity, and rapid performance of postcontrast sequences.[5] Bilateral imaging allows for assessment of symmetry and comparison of enhancement, particularly helpful in premenopausal women, and should be performed routinely.[1] Since the advent of parallel imaging, bilateral breast imaging does not compromise spatial resolution,[7] which was required for lesion morphology characterization, or temporal resolution, which was required for dynamic enhancement assessment.[5] Effort should be made to minimize scan time for patient comfort and avoidance of motion-related artifact.

Where an undersized FOV can lead to reduced signal wrap-around artifact (discussed further later), care should be taken to avoid an oversized FOV that would reduce pixel size and spatial resolution.

The FOV must also be carefully determined in the section-select direction to avoid incomplete anatomical coverage, while maximizing spatial resolution and maintaining temporal resolution.

* Reprint requests: Marina-Portia Anthony, Department of Radiology, Columbia University Medical Center, Milstein 3, New York Presbyterian Hospital, Fort Washington Ave, New York, NY.

E-mail address: ma3415@columbia.edu (M.-P. Anthony).

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Table 1
Typical technical parameters for the 1.5-T breast MRI protocol at our institution

Parameter	Sagittal T1 volume	Sagittal T1 volume pre-post	Sagittal T2 fat sat	Axial T1 volume post delayed
TR* (ms)	6.103	4.949	3800	5.153
TE* (ms)	2.4	1.716	92.368	2.1
Flip angle (deg)	10	10	90*	10
FOV (mm)	22	22	22	33
Matrix	256 × 256	262 × 262	256 × 192	256 × 256
Slice thickness (mm)	2.2	2.2	3	1.8
Spacing (mm)	1.1	1.1	3	0.9
Bandwidth (Hz/pixel)	31.25	31.25	31.25	41.67

fat sat, fat saturated.
Many parameters, as indicated by asterisk (*), are variable depending on patient factors.

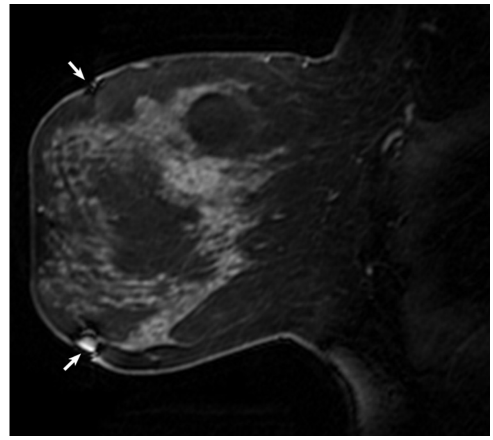

Fig. 1. Poor positioning of breast in coil. A sagittal T1 fat-suppressed (FS) postcontrast image with focal signal distortion and uneven fat suppression at the indented margins of the anterior breast superiorly and inferiorly (arrows).

Ideally, coverage should be from the clavicle to the inframammary fold to include assessment for axillary lymphadenopathy.

A number of strategies may be required for achievement of homogeneous fat suppression in breast MRI, which is critical for the detection of cancer, but it is difficult to achieve because of the high fat composition of the breasts.[8] The center frequency for the application of a fat suppression pulse must be set to the water peak as accurately as possible, and shimming volumes should be positioned correctly to improve field inhomogeneities.[9] In the setting of inadequate fat suppression, subtraction imaging may be helpful when the fat-suppressed T1-weighted images are themselves uninterpretable. At 3 T field strength, uniform fat saturation can be particularly difficult to achieve, as field homogeneity can be difficult to maintain; however, there is better separation of the fat and water peaks, which is useful in selection of the center frequency.

The standard parameters for breast MRI used at our institution are presented in Tables 1 and 2.

Patient-Related Artifacts

Positioning and Breast Size

Suboptimal positioning of the breasts or breasts that are too large for the selected coil can cause pressure on the coil or compression of the breasts, leading to signal distortion, uneven fat suppression, or uneven enhancement. For example, if the coil is excessively compressing the breast in an attempt to improve SNR, near-field artifact may be produced. This is seen as hyperintensity at the site of contact, potentially leading to a false-positive interpretation of the signal hyperintensity as a lesion.[10] Currently, only 1 breast coil size is available, although different sizes would help eliminate these artifacts, as well as improve SNR and patient comfort.

Technologists should be trained in proper patient positioning. The goal is to maximize the amount of breast tissue scanned while minimizing skin folds and breast distortion. Any prior imaging should be reviewed to anticipate potential positioning difficulties.[11] The localizer images should be checked for proper positioning of the breasts within the coil before obtaining diagnostic sequences. The breasts should be positioned symmetrically within the coil with nipples centered and pointing down. Techniques such as changing the arm position and rolling the patient may be considered, as well as using aids such as padding and angled foam cushions.[11]

Positioning the patient's arms by her sides promotes relaxation of the pectoralis muscles, which can prevent muscle contraction between sequences and artifactual simulation of a mass or enhancing focus.[10] It also allows the breasts to sink deeper into the coil, which enables better coverage of posterior breast tissue and smaller breasts. Most importantly, the patient should be comfortable enough to remain in position and relaxed for the duration of the scan.[10]

Conversely, positioning the patient's arms above the head allows for a smaller FOV limited to the area of the breasts, with less concern for phase wrap-around artifact from the arms, and with associated better spatial resolution. However, in some instances, the patient may not be able to position the arms above the head because of pain or prior injury (Figs 1 and 2).

Table 2
Typical technical parameters for the 3-T breast MRI protocol at our institution

Parameter	Sagittal T1 volume	Sagittal T1 volume pre-post	Sagittal T2 fat sat	Axial T1 volume post delayed
TR* (ms)	6.894	5.562	3750	6.669
TE* (ms)	2.476	1.776	85.512	2.136
Flip angle (deg)	10	10	90*	10
FOV (mm)	20	20	20	26
Matrix	256 × 224	262 × 262	288 × 256	320 × 320
Slice thickness (mm)	2.2	2.2	3	1.8
Spacing (mm)	1.1	1.1	3	0.9
Bandwidth (Hz/pixel)	50.00	50.00	41.67	83.33

fat sat, fat saturated.
Many parameters, as indicated by asterisk (*), are variable depending on patient factors.

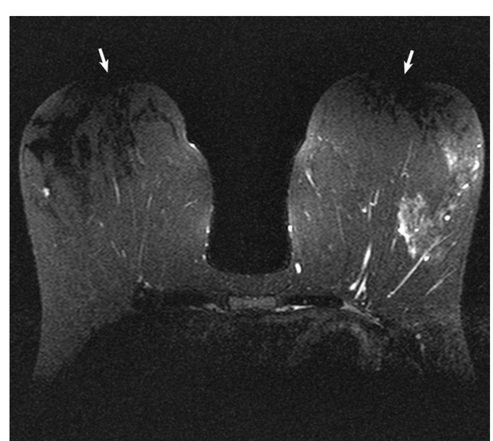

Fig. 2. Breasts too large for coil. An axial T1 FS postcontrast image in another patient with signal loss (arrows) in the anterior aspects of the breasts because of the breasts pressing against the coil elements.

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