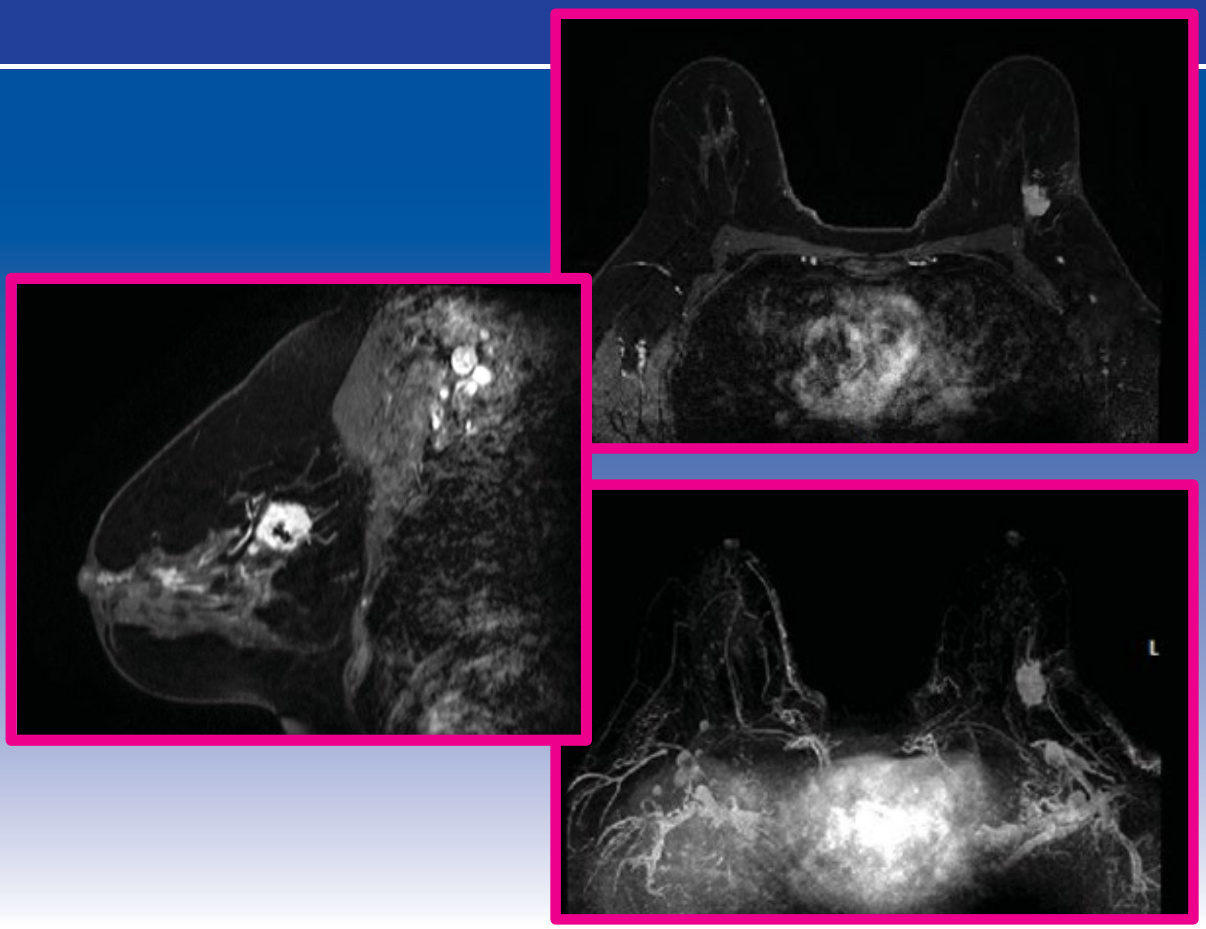
Advancements in Breast MRI Protocols: Optimizing Visualization

1st Edition



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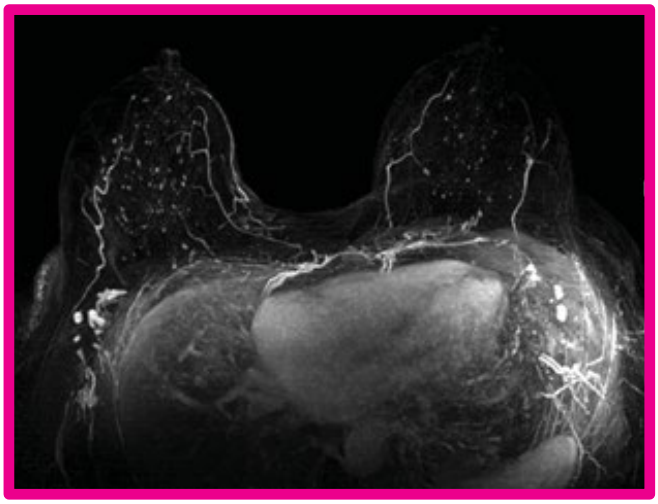

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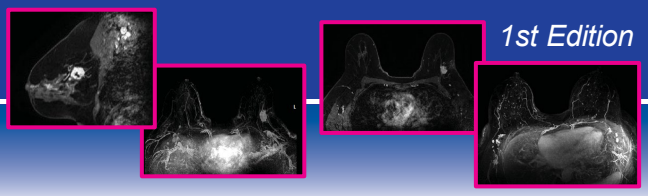


BREAST MR PROTOCOLS

Breast magnetic resonance imaging (MRI) requires maximizing sensitivity and specificity for breast cancer while minimizing scan time. Only with the use of modern MRI equipment, appropriate imaging sequences, proper patient positioning, appropriate contrast agent administration, and standardized image acquisition and interpretation will sensitivity for breast cancer be maximized. Evaluation of lesion morphology and appropriate post-contrast imaging timing are required for the detection and characterization of abnormal findings and to improve specificity and diagnostic accuracy. Longer overall scan times should be avoided, as they can lead to patient discomfort and motion, which in turn lead to artifacts and image degradation secondary to motion. See **Table 1** for a summary of the prerequisites for maximizing sensitivity and specificity of breast MR imaging.[1-3] In addition, the following text provides some additional details, as well as tips to consider, when performing breast MRI.

Table 1: Summary of Prerequisites for Maximizing the Sensitivity and Specificity of Contrast-enhanced Breast MR Imaging[1-3]

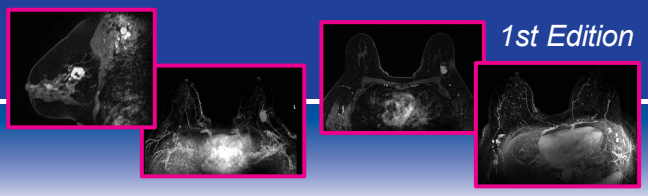
• High magnetic field strength (1.5T or greater) with a highly homogeneous magnetic field (<1 ppm over 30 cm)
• Bilateral image acquisition with a prone-positioning bilateral breast coil (7 channels or greater)
• Unenhanced imaging with a T2-weighted pulse sequence to identify cysts and contribute to lesion characterization
• If full protocol, pre- and multiphase contrast-enhanced imaging with a 3D T1-weighted spoiled gradient-echo pulse sequence
• If abbreviated protocol, pre- and single contrast phase enhanced imaging with a 3D T1-weighted spoiled gradient-echo pulse sequence
• Phase-encoding direction selected to minimize artifacts across breast tissue: phase-encoding right-to-left for axial imaging, head-to-foot for sagittal imaging (frequency-encoding anterior-posterior in either case)
• Standardized weight-based intravenous administration of a gadolinium-based contrast agent at doses specified below
• Homogeneous fat removal across both breasts
• Thin-section acquisitions (section thickness of 3 mm or less, ideally closer to 1 mm) for the multiphase T1-weighted contrast-enhanced series
• Pixel size of less than 1 mm in each in-plane direction for the multiphase T1-weighted contrast-enhanced series
• Temporal resolution (i.e., per-series imaging time) of less than 3 minutes for imaging both breasts in the multiphase T1-weighted contrast-enhanced series
• Field of view selected to smallest allowable that includes both breasts (including axillary tail) and axillae completely

Protocol Sequences

The American College of Radiology (ACR) Breast MRI Accreditation Program requires submission of a biopsy-proven breast carcinoma case acquired bilaterally with the following pulse sequences:[2]

- Localizer or scout images, preferably obtained in all 3 perpendicular planes: axial, sagittal, and coronal
- A T2-weighted (T2W)/bright fluid series of both breasts, preferably with fat removal, to distinguish cysts from solid lesions
- A multiphase T1-weighted (T1W) series set acquired once before and at least two times after contrast agent administration, preferably acquired as a 3D (volume) gradient-echo (GRE) pulse sequence with fat removal, to identify the vascular bed and detect enhancing lesions in the breast

In addition, it is common to obtain a 3D T1W non-fat-suppressed series, prior to the multiphase series, to provide an overview of breast anatomy and to distinguish fat from water-based tissues (fibroglandular tissues, chest wall, and breast lesions).[3]



The multiphase dynamic contrast-enhanced (DCE) sequences (i.e., pre- and postcontrast T1W, preferably with fat removal) are the most important images for identifying and characterizing lesions. The number and length of the individual DCE sequences is variable, but each acquisition is required to have high spatial resolution (pixel size of 1 mm or less and slice thickness 3 mm or less) per ACR guidelines. It is essential that the pre- and postcontrast technical parameters are identical so that precontrast images can be subtracted from postcontrast images. This will provide a valid subtracted series from which other post-processed images (e.g., orthogonal plane reformatted images and maximum-intensity projections [MIPs]) can be reconstructed. One of the postcontrast phases should be obtained at the early phase approximately 90 seconds after contrast administration, when potential malignancies are avidly enhancing and benign background parenchymal enhancement is lower, typically referred to as the "peak" postcontrast phase. The protocol sequences and sequence timing should be as consistent as possible from patient to patient, regardless of breast size or body habitus, to maximize spatial resolution while including all breast tissue.

It is important to be as efficient as possible, collecting the necessary information in the shortest exam time. Exams that take up to 45 minutes or longer are challenging for patients and increase the chance that the patient will experience discomfort and move, causing motion artifacts and image misregistration. This is particularly problematic for the DCE T1W series set, which is typically acquired last. Motion during the DCE series set can significantly compromise kinetic evaluation, subtracted images, MIPs, and other reformatted images. When appropriately constructed and performed on modern equipment, standard diagnostic breast MRI protocols should be completed within 30 minutes, including non-scan time.

Abbreviated Breast MRI (AB-MR)

AB-MR is a new protocol for screening women at elevated risk of breast cancer.[4,5] Although there is no standard definition, AB-MR is a short scanning protocol typically 10 minutes or less consisting of scout images, a precontrast fat-removed T2W series, precontrast T1W series with fat removed, contrast injection, and a brief (20-45 seconds depending on the series acquisition time) delay to permit perfusion of contrast agent, followed by an identical T1W fat-removed postcontrast series. The entire acquisition protocol should require no more than 10 minutes of scanning.[6-8] Image post-processing should include subtraction of pre- from postcontrast images and reconstruction of MIP images. Image acquisition techniques for pre- and postcontrast T1W images should follow the same optimization procedures as those used for dynamic breast MRI, with the exception that only a single postcontrast series is acquired.

Initial clinical results for AB-MR show high sensitivity and specificity, comparable to those of the full dynamic protocol used for diagnostic breast MRI.[4,5,7,9-15] The results of the ECOG-ACRIN 1141 trial using AB-MR in addition to digital breast tomosynthesis (DBT) to screen patients with heterogeneously or extremely dense breasts demonstrated a significantly increased cancer detection rate using AB-MR compared with DBT alone.[8,16]

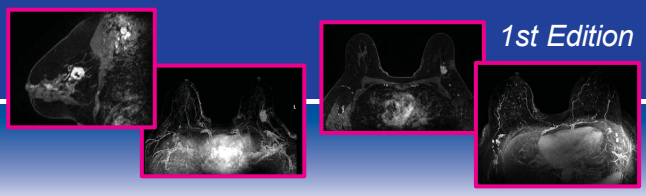
Coils

Per the ACR, a dedicated, bilateral breast coil is required.[2] Modern bilateral breast coils commonly have 7 to 16+ channels to improve signal uniformity and intensity. An increased number of channels is desirable.

Contrast

Currently, seven extracellular fluid (ECF) gadolinium-based contrast agents (GBCAs) are being used for breast MRI (**Table 2**).[17-26] Of these contrast agents, only three—Gadavist (gadabutrol) and Vueway/Elucirem (gadopiclenol)—have been FDA-approved specifically for use in breast MRI. The other ECF agents shown in **Table 2** are FDA-approved for use in imaging the central nervous system (CNS) and other body areas/applications, but they are often used "off-label" for breast MRI.

In 2022, a new GBCA, gadopiclenol, was approved for clinical use by the FDA. It is marketed under the brand names Vueway (Bracco Diagnostics, Inc) and Elucirem (Guerbet, LLC). Gadopiclenol represents the first high-relaxivity macrocyclic GBCA to enter clinical practice,[24,25] and also has high kinetic stability.[26] Vueway (gadopiclenol) provides a r1 relaxivity of 12.8 at 1.5 T and 11.6 at 3T in human serum, and consistently retains its high relaxivity at 3T (**Table 2**).[26] Vueway (gadopiclenol) also demonstrates high kinetic stability in acidic conditions with a dissociation half-life of 20±3 days, as compared to Clariscan/Dotarem (gadoterate meglumine) 4±0.5 days, Gadavist (gadobutrol) 18 hours, and ProHance (gadoteridol) 4 hours.[26] Unlike other extracellular agents (Clariscan/Dotarem [gadoterate meglumine], Gadavist [gadobutrol], and ProHance [gadoteridol]) and the combined extracellular/hepatobiliary agent MultiHance (gadobenate dimeglumine), Vueway (gadopiclenol) is approved at 0.05 mmol/kg instead of 0.1 mmol/kg, thereby reducing gadolinium exposure by half as compared to other GBCAs. Having the ability to reduce gadolinium exposure by using lower doses of GBCAs is ideal, particularly in patients undergoing serial MRI exams, pediatric patients, and patients undergoing MRI for



screening (such as patients undergoing breast MRI). Vueway/Elucirem (gadopiclenol) is currently indicated to detect and visualize lesions with abnormal vascularity in the CNS (brain, spine, and associated tissues) and the body (head and neck, thorax, abdomen, pelvis, and musculoskeletal system) in patients ≥2 years.[24,25]

Vueway (gadopiclenol) provides clinicians with the ability to halve the gadolinium dose while maintaining comparable lesion visualization.[27-29] The PROMISE Trial was a phase III multicenter, prospective, randomized, double-blinded, controlled crossover study conducted at 33 centers in 11 countries.[27] A total of 300 adult patients with at least one suspected focal lesion in one of three different body regions (head and neck; breast, thorax, abdomen, or pelvis; or musculoskeletal system) underwent two MRI scans: one with Vueway (gadopiclenol; 0.05 mmol/kg) and one with Gadavist (gadobutrol; 0.1 mmol/kg) in randomized order. MRI examinations were read by three blinded readers who were experts for each respective body region imaged and three additional readers assessed reader preference. The study's primary objective was to demonstrate noninferiority of contrast-enhanced MRI with Vueway (gadopiclenol) vs Gadavist (gadobutrol) for lesion visualization. Secondary objectives included overall preference for either Vueway (gadopiclenol) or Gadavist (gadobutrol) and lesion visualization assessed by radiologists on site. Adverse events were also recorded and evaluated.

A total of 260 subjects without protocol deviations were analyzed for this noninferiority study. The PROMISE Trial demonstrated that Vueway (gadopiclenol) at 0.05 mmol/kg was noninferior to Gadavist (gadobutrol) at 0.1 mmol/kg for all qualitative visualization parameters and for all readers (lower limit 95% CI of the difference of at least −0.10, which was above the noninferiority margin [−0.35]; $P<.001$). For most subjects (75%-83% [206-228 of 276]), the readers reported no preference between Vueway (gadopiclenol) and Gadavist (gadobutrol) enhanced images. The trial's safety analysis did not find any difference in frequency, intensity, or type of adverse events for either agent; most adverse events were mild.[27]

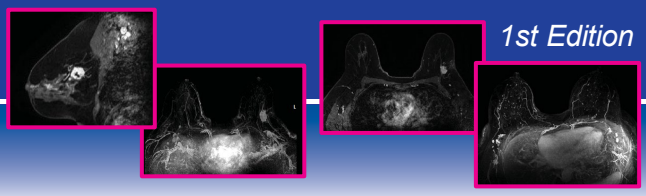
The investigators suggested that a high-relaxivity macrocyclic GBCA such as Vueway (gadopiclenol) should preferably be used for contrast-enhanced MRI in individuals who require serial contrast-enhanced MRI examinations, pediatric patients, and patients with impaired renal function.[27]

Separately, a phase I trial by Bradu et al. studied the pharmacokinetics and safety of Vueway (gadopiclenol) in patients with impaired renal function.[30] In this two-center open-label study, five successive cohorts of eight adult subjects were enrolled. Cohort 1 included healthy subjects, cohort 2 included subjects with mild renal disease, cohort 3 included subjects with moderate renal disease, cohort 4 included subjects with severe renal disease, and cohort 5 included subjects with end-stage renal disease (ESRD). All subjects received an IV injection of Vueway (gadopiclenol) dosed at 0.1 mmol/kg, i.e., twice the indicated dose. Blood and urine samples were collected at different time points in cohorts 1 to 4, and blood and dialysate samples were collected at each hemodialysis session (4-hour session on day 1, day 3, and day 5) in cohort 5. Vueway (gadopiclenol) elimination and safety were assessed for up to 6 months.

This study demonstrated that there was decreased renal clearance of Vueway (gadopiclenol) that resulted in an increased elimination half-life of this agent in patients with mild to severe renal impairment, but elimination was complete or nearly complete within 7 days.[30] In patients with ESRD, Vueway (gadopiclenol) was effectively removed from the plasma after the first hemodialysis session, and no more than three hemodialysis sessions were required to completely clear Vueway (gadopiclenol). The investigators concluded that there were no safety concerns in regard to administering Vueway (gadopiclenol) to patients who have mild to severe renal disease including ESRD, and no dose adjustment seems necessary in this population.

It should be noted that while clinical experience with Vueway (gadopiclenol) has been limited to date, the ACR decided to classify this agent as a group II agent (associated with few, if any, unconfounded cases of NSF) because it demonstrates kinetic stability and a long dissociation half-life comparable to other group II agents.[31]

All of the available GBCAs exhibit the same mechanism of action; they increase signal intensity of lesions against background tissue, a phenomenon known as T1-shortening. The degree to which a GBCA can cause T1-shortening is known as relaxivity (r1). At a given molar concentration of GBCA, a higher r1 relaxivity translates into greater T1-shortening, and subsequently a greater effect of a GBCA on lesion conspicuity and breast cancer detection.[3,32]



The newest GBCA on the market, Vueway (gadopiclenol), has approximately twice the relaxivity of the next highest relaxivity agent, MultiHance (gadobenate dimeglumine).[24] For breast MRI, Vueway (gadopiclenol) is administered at a dose of 0.05 millimoles per kilogram (mmol/kg) of body mass.[24] The remaining standard and higher-relaxivity contrast agents should be administered at labeled doses of 0.1 mmol/kg of body mass.[17-21] All agents are injected at a rate of 2 milliliters per second (mL/s), followed by a 20-mL saline flush injected at the same rate. Use of a power injector to inject both the contrast agent and the saline flush is necessary for reliable contrast injection timing.

Table 2: FDA-Approved Extracellular Gadolinium-Based Contrast Agents and Their Properties[17-26]

Brand Name (Manufacturer) FDA Approval Date	Generic Name	Approved Indications	Approved Dose	Molarity (M, moles per liter)	r1 Relaxivity ($mL \cdot mmol^{-1}s^{-1}$) at 1.5T/3.0T in Plasma at 37°C
Vueway (Bracco) 2022 Elucirem (Guerbet) 2022	Gadopiclenol	CNS (brain, spine, and associated tissues), adults & pediatrics ≥2 years; Body (head and neck, thorax, abdomen, pelvis, and musculoskeletal system), adults & pediatrics ≥2 years	0.05 mmol/kg	0.5	12.8 / 11.6
ProHance (Bracco) 1992	Gadoteridol	CNS, adults & pediatrics (including term neonates); Head and neck, adults	Adults: 0.1 mmol/kg + 2nd dose of 0.2 mmol/kg up to 30 min after 1st dose; pediatrics: 0.1 mmol/kg	0.5	4.39 / 3.46
MultiHance (Bracco) 2004	Gadobenate dimeglumine	CNS, adults & pediatrics (including term neonates); MRA in adults, to evaluate known or suspected renal or aorto-ilio-femoral occlusive vascular disease	Adults & pediatrics ≥2 years of age: 0.1 mmol/kg; pediatrics <2 years of age: 0.05-0.1 mmol/kg (ie, 0.1-0.2 mL/kg) (CNS)	0.5	6.2 / 5.37
Gadavist (Bayer Healthcare) 2011	Gadobutrol	CNS, adults & pediatrics (including term neonates); Assess presence and extent of malignant breast disease; MRA to evaluate known or suspected supra-aortic or renal artery disease in adults & pediatrics (including term neonates)	0.1 mmol/kg	1.0	4.61 / 4.46
Dotarem (Guerbet) 2013 Clariscan (GE HealthCare) 2013	Gadoterate meglumine	CNS, adults & pediatrics (including term neonates)	0.1 mmol/kg	0.5	3.91 / 3.43

CNS = central nervous system; MRA = magnetic resonance angiography.

Image Interpretation

Image interpretation steps include:

1. Identification of enhancing findings separate from background parenchymal enhancement.
2. Characterization of morphologic characteristics of identified lesions according to the latest version of the *ACR Breast Imaging Reporting and Data System (BI-RADS) Atlas*.[33]
3. Evaluation of temporal kinetics, if available (i.e., if there are multiple postcontrast phases), of identified findings according to the *ACR BI-RADS Atlas*.
4. Use of both morphology and kinetics, if available, to make a recommendation regarding level of suspicion according to the *ACR BI-RADS Atlas*.

Computer-aided Evaluation (CAE) Systems

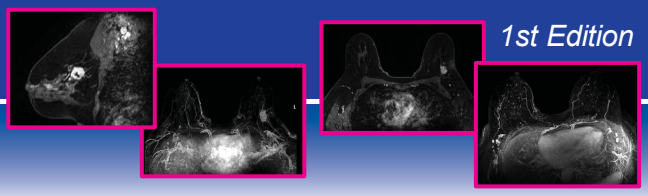
Several computer-aided evaluation (CAE) systems are available for breast MRI. CAE for breast MRI, unlike computer-aided detection (CAD) for mammography, does not direct the interpreting radiologist to potentially suspicious lesions; rather, it aids in evaluation of lesion kinetics and overall assessment of the degree of suspicion. CAE provides a convenient and efficient way to visually and quantitatively assess temporal kinetic information by providing color overlay maps and time-signal intensity curves of enhancing lesions.

With modern CAE systems, images are sent from the MR system to the picture archiving and communication system (PACS) and the CAE system, where color overlay maps, kinetic analyses, image subtractions, and multiplanar and MIP reconstructions are performed. When the radiologist identifies a suspicious area of enhancement, the CAE software provides information on lesion size, degree of early-phase enhancement, and the signal-intensity time course including the delayed-phase enhancement pattern (persistent, plateau, wash-out), which correlates with degree of suspicion of breast cancer.[34]

Note that CAE systems impose a delay between receipt of images from the MR or PACS system and availability of processed results to the radiologist. Importantly, CAE-subtracted images and temporal kinetic evaluation are susceptible to patient motion between pre- and postcontrast images; if unrecognized as motion artifacts, it is possible to misinterpret displaced tissue color maps or signal-intensity time curves as enhancing lesions. All or most CAE systems have motion correction algorithms, but they are not perfect, and evaluation by the interpreting radiologist requires assessment of the pre- and postcontrast images for motion to avoid these mistakes.

Use of CAE temporal kinetic color overlay maps alone can lead to overestimation or underestimation of the degree of suspicion of a lesion due to the overlap in the kinetics of benign and malignant lesions, as well as misinterpretation of artifacts created by patient motion. For example, unrecognized motion can result in “wash-out” kinetics and overestimation of lesion suspicion, while the lack of the more concerning plateau or wash-out delayed-phase enhancement patterns on CAE can cause underestimation of the level of suspicion for small, low-grade, or non-mass-like lesions such as ductal carcinoma in situ (DCIS). If a lesion has suspicious morphologic features, the level of suspicion generated by the concerning morphologic features should not be diminished by the presence of a less suspicious temporal kinetic signal-intensity time course, such as persistent delayed-phase enhancement.

CAE color map thresholds for standard agents should be set at values of 50% and 100% signal enhancement above precontrast levels, whereas use of higher thresholds may be helpful when using a high-relaxivity agent (such as MultiHance [gadobenate dimeglumine] or Vueway [gadopiclenol]). Systems that allow for real-time adjustment of CAE thresholds may allow more flexibility. It is especially important to make the color map threshold adjustment if CAE images from an exam performed with a high-relaxivity agent are being compared to CAE images from an exam performed with a conventional-relaxivity agent in the same patient. There is usually no need to make additional adjustments to CAE thresholds when changing between breast MRI exams performed at 1.5T and 3T.



Tips for Maximizing Sensitivity and Specificity

To maximize sensitivity, it is important to acquire T1W images with high spatial resolution (i.e., sub-millimeter in-plane resolution in the frequency- and phase-encoding directions) to obtain morphologic detail, including lesion shape, margin, and internal enhancement pattern. It is also important to acquire thin slices; if the slices are not sufficiently thin, there is the risk of volume-averaging small, subtle lesions with background tissue, decreasing their lesion conspicuity. In addition, the use of thin slices (nearly isotropic voxels, where the slice thickness is nearly as small as the in-plane resolution) allows image reconstruction in any plane while maintaining approximately the same spatial resolution as acquired in-plane images. On the other hand, pixel size and slice thickness should not be so small that signal-to-noise ratios suffer. Thus, ensuring that the field-of-view does not get reduced so much that SNR is too low is important. Finally, radiologists should identify enhancing lesions on the early-phase (peak) postcontrast or subtracted images obtained ~90 seconds after contrast administration, where the signal difference between enhancing lesions and background parenchyma is greatest.

To maximize specificity in the multiphase postcontrast protocol, kinetics should be obtained with a temporal resolution of 3 minutes or less (that is, each series in the multiphase set should be acquired in 3 minutes or less). While there are studies showing that proper lesion time-intensity curve shape can be captured with 2 minute and 3 minute temporal resolution (or less),[35,36] there are no data to suggest that curve shapes are captured correctly with longer acquisition times. Conversely, there is a trade-off between temporal resolution and signal-to-noise, just as there is between temporal resolution and spatial resolution.[35] Using very rapid acquisitions, just like using excessively small voxels, can reduce signal-to-noise ratios to the extent that enhancing lesions, especially non-mass lesions, are not detected. More recent advanced MRI sequences allow for faster acquisitions without traditional compromises in spatial resolution using undersampling and advanced reconstruction techniques such as view-sharing and compressed sensing. However, all of these techniques have trade-offs, and if they are being used, it is important to understand how these sequences obtain and reconstruct images in order to maximize benefits and minimize drawbacks.

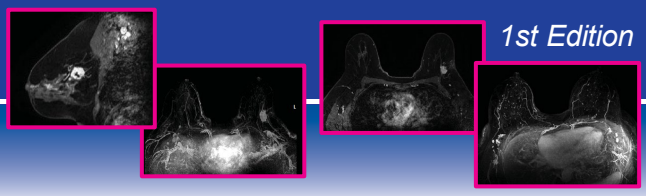
It is beneficial to evaluate the breasts in at least one additional imaging plane beyond the primary acquisition plane (e.g., if the primary image acquisition plane is axial, be sure to also evaluate sagittal reformatted images). Again, it is most beneficial to do this in peak contrast enhancement, where the contrast difference between enhancing lesions and background parenchyma is greatest. Therefore, reconstruction of images in other planes from peak images acquired with isotropic or nearly isotropic voxels is most beneficial for this analysis and shortens the overall scan time (instead of acquiring additional postcontrast series in additional scan planes after the multiphase T1W series has been acquired).

Breast MR: Practical Considerations

There are no additional MR safety considerations specific to breast MRI; the biggest safety hazard while performing breast MR, like other MR exams, is the inadvertent introduction of ferromagnetic materials (iron-, nickel-, or cobalt-containing metals) into the scanner room. Such metals may be implanted in the patient, worn by the patient, or inadvertently brought in by the patient, someone accompanying the patient, or by a physician, technologist, or maintenance personnel. Ferromagnetic materials near the bore of the scanner are rapidly accelerated into the scanner bore and can severely injure the patient or others in the scan room. Additional considerations include burns. The MR safe practice guidelines developed by the ACR to establish industry standards for safe and responsible practices in clinical and research MR environments also apply to breast MRI.[37]

In addition, as for other contrast-enhanced MR exams, women undergoing breast MR exams may need to be screened for adequate renal function (glomerular filtration rate) prior to performing the breast MR exam, per institutional and ACR guidelines.[31]

During the past several years, multiple published studies have reported high signal intensity in tissues within the deep nuclei of the brain in patients who have undergone repeat contrast-enhanced MRIs. These hyperintense areas are noted principally in the globus pallidus and the dentate nucleus. The persisting changes in signal intensity have been associated with the retention of gadolinium from GBCAs, and most of the patients cited in these reports have normal renal function.[38-43] These findings have led to concerns about the long-term safety of GBCAs and raise the question as to whether retention from GBCAs could be harmful. To date, no studies or substantiated case reports have demonstrated any adverse clinical effects in humans or mammals caused by gadolinium retention in the brain.[38] Linear GBCAs have been reported to have higher rates of retention than macrocyclic agents. At this time, gadolinium retention has not been associated with symptoms, but considering this phenomenon is important.[38] Especially in the screening setting in which patients will likely be exposed to repeated doses of GBCAs for many years, selection of a GBCA with a high safety profile and lowest possible dose is important while maintaining diagnostic accuracy.



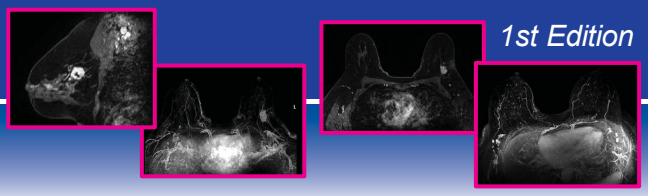
In 2018, the FDA added additional information about the potential for gadolinium deposition to all GBCA package inserts as well as a patient medication guide. Because many patients do not have convenient access to package inserts or are not interested, some healthcare centers have developed their own GBCA information sheets.

Additional practical considerations include patient size and patient breast size. Larger patients may not fit into the scanner itself, particularly when positioned on the breast coil. Very large or very small breasts may not fit well in the breast coil, and good breast positioning, including as much breast tissue in the breast coil as possible, is important for optimal image acquisition and interpretation.[44] Technologists performing breast MRI should take care to ensure that as much breast tissue as possible is positioned inside the breast coils, that breast positioning is as symmetric as possible between the left and right breasts, and that the nipple is positioned centrally and symmetrically in each breast. It is particularly important to make sure that the nipple is not folded inside other breast tissue. Ensure that axillary tail breast tissue is pulled into the coil. Smoothing and pulling down the abdominal tissue is often more comfortable for the patient and opens the inframammary fold. It also is important to stabilize the breast to minimize motion by bringing in the lateral breast coil, while at the same time avoiding compression and deformation of the breast. Radiologic technologists performing breast MR should be trained on proper breast positioning,[44] and experienced technologists and coil manufacturer applications specialists can be helpful in providing such training. In addition, the ACR Breast MRI Accreditation Program requirements for technologist experience and training should be reviewed and followed.[2]

Additional Tips for Technologists Performing Breast MRI

Every effort should be made to ensure the patient is comfortable in the prone positioning used for breast MRI. This includes proper head support, adequate padding between the sternal notch and the breast coil, where a large portion of the patient's weight is supported, and positioning arms and legs comfortably with pads, as needed.

- During patient positioning, make sure that IV contrast lines remain unkinked and positioned for maximum comfort and flow at the injection site
- Make sure that the appropriate patient positioning (head-first prone or feet-first prone) is entered during patient data entry. Incorrectly entering supine instead of prone, or reversing head-first and feet-first, will reverse left and right on the images, which can lead to identification of lesions in the wrong breast during interpretation. Breast MRI patients imaged on GE (and Aurora) scanners are typically positioned feet-first prone (FFP), while patients imaged on Siemens and most other manufacturers' scanners are typically positioned head-first prone (HFP)
- Always inform the patient about the importance of not moving during scanning and not moving between pre- and postcontrast multiphase T1W series. This is best done prior to the precontrast series, rather than just prior to injection, to avoid causing the patient to startle and move between pre- and postcontrast series, which affects the registration of subtracted images. Advice about the injection is best given prior to the precontrast series
- If active fat removal is being used for the multiphase T1W images, always check precontrast images for adequate fat suppression prior to injection of contrast agent
- Always check postcontrast images as soon as possible to confirm that contrast agent injection was successful. This is best done by comparing precontrast and postcontrast images viewed with similar window width and level settings and looking for the presence of contrast agent in the heart and internal mammary vessels. If contrast agent is not visible in postcontrast images, the patient injection site should be checked for extravasation of contrast agent into tissues surrounding the injection site, failure to inject into the patient (i.e., the contrast agent is on the table), and failure of the power injector, including loading of contrast agent and saline. If contrast agent appears not to have been injected, a second attempt at the multiphase series may be feasible; if agent was injected but does not appear on the images, the patient may need to be rescheduled for the exam. In either case, the radiologist should be consulted to determine if medical management is needed
- Checking enhancement in the heart on postcontrast images also affords the opportunity to double-check that proper patient positioning was entered by confirming that the heart is on the left side of the body, although rare exceptions to this rule do occur (about 1 in 12,000 women have dextrocardia, where their heart is on the right)



- All images should be checked for image quality and patient motion prior to termination of the exam. If image quality problems occur, the interpreting radiologist should be consulted
- If problems with positioning, contrast agent administration, or image acquisitions occur, the appropriate supervising radiologist or interpreting breast MRI radiologist should be notified. Any problems or issues complicating the exam should be clearly communicated to the interpreting radiologist as soon as possible

Summary

Breast MRI is one of the most technically challenging clinical applications of MR imaging. Only with modern MR equipment, optimized breast imaging protocols, careful attention to patient comfort, patient positioning, proper administration of contrast agent and proper imaging by the MR technologist, and appropriate image display, post-processing, and interpretation by the radiologist, can the sensitivity and specificity of breast MRI for cancer be maximized.

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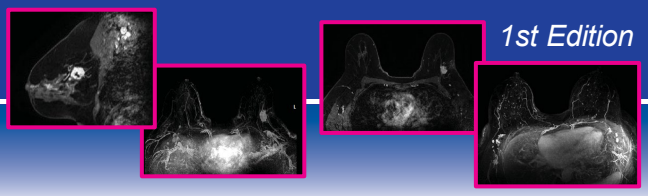

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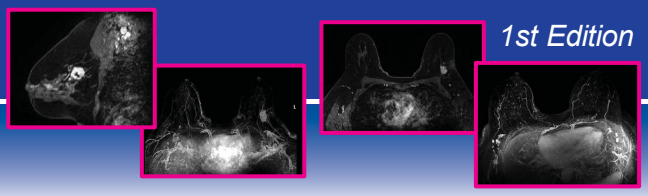

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