

# ACR PRACTICE PARAMETER FOR THE PERFORMANCE OF CONTRAST-ENHANCED MAGNETIC RESONANCE IMAGING (MRI) OF THE BREAST

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The American College of Radiology will periodically define new practice parameters and technical standards for radiologic practice to help advance the science of radiology and to improve the quality of service to patients throughout the United States. Existing practice parameters and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice parameter and technical standard, representing a policy statement by the College, has undergone a thorough consensus process in which it has been subjected to extensive review and approval. The practice parameters and technical standards recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice parameter and technical standard by those entities not providing these services is not authorized.

## PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care<sup>1</sup>. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner considering all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The purpose of this document is to assist practitioners in achieving this objective.

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<sup>1</sup> *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing*, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the "ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures (Revised 2008)" sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, *Stanley v. McCarver*, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

## I. INTRODUCTION

Magnetic resonance imaging (MRI) of the breast is a useful tool for the detection and characterization of breast cancer, assessment of local disease extent, evaluation of neoadjuvant treatment response, and guidance for biopsy and localization. MRI findings should be correlated with the clinical history, physical examination findings, and results of any recent breast imaging.

## II. INDICATIONS AND CONTRAINDICATIONS

A. Current indications for breast MRI include, but are not limited to, the following:

1. High-risk screening
  - a. Patients with greater than or equal to 20% lifetime risk (eg, genetic predisposition, history of mantle radiation for Hodgkin lymphoma) [1-14].
  - b. Patients with a personal history of breast cancer and dense breast tissue, or those diagnosed with breast cancer under age 50 [15-20].
2. Evaluate the extent of disease with newly diagnosed breast cancers
  - a. Characterize and detect ipsilateral and contralateral ductal carcinoma in situ and invasive carcinoma, particularly invasive lobular carcinoma [21-31].
  - b. Determine the invasion of underlying fascia and muscle [32-34].
  - c. Neoadjuvant treatment response assessment [35,36].
3. Metastatic cancer when the primary is unknown and suspected to originate from breast [37-40].
4. Pathologic nipple discharge with no abnormality on diagnostic mammography or ultrasound [41,42].
5. Lesion characterization: when other diagnostic imaging examinations, such as ultrasound and mammography, and physical examination are inconclusive or when biopsy cannot be otherwise performed [43-50].
6. Breast augmentation: implant integrity can be determined by noncontrast breast MRI, but the use of contrast may be indicated in patients with free injections of silicone, paraffin, or polyacrylamide gel in whom mammographic screening may be compromised. Additionally, patients who have undergone implant reconstruction following lumpectomy or mastectomy may benefit from contrast-enhanced breast MRI screening.

B. Other Considerations

1. Treatment planning  
MRI findings in patients with breast cancer may change their planned treatment. Caution should be exercised in altering management based on MRI findings alone without biopsy confirmation.
2. Inappropriate uses of breast MRI  
MRI should not supplant careful problem-solving mammographic views or ultrasound in the diagnostic setting. MRI should not be used in lieu of biopsy of a suspicious finding identifiable by mammography, ultrasound, or clinical examination.
3. Abbreviated MRI protocols  
Studies with reported shortened or abbreviated MRI protocols have similar sensitivities and specificities compared with a full MRI protocol [51-57]. This practice parameter document is specific to conventional breast MRI because the utility and protocols for abbreviated MRI are under investigation.
4. Diffusion-weighted imaging  
Studies have reported that diffusion-weighted imaging has the potential to improve the specificity of breast MRI by better characterizing lesions as benign versus malignant [58]. Optimal scanning and interpretation protocols remain under investigation

C. Contraindications

Possible contraindications include, but are not limited to, the presence of cardiac pacemakers, ferromagnetic intracranial aneurysm clips, neurostimulators, cochlear implants, some intrauterine devices, and certain other ferromagnetic foreign bodies or electronic devices [59-63]. Due to the unknown effects of gadolinium contrast on the fetus, contrast-enhanced breast MRI is contraindicated in pregnant women

[59]. All patients should be screened for potential contraindications prior to MRI scanning [64,65]. All general MR safety precautions should be observed, and gadolinium risk should be assessed [36-41,43,44]. For further information, see the [ACR Manual on Contrast Media](#) [59] and the [ACR Manual on MR Safety](#) [66].

### III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the [ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#) [67].

Interpreting physicians should have knowledge and expertise in breast disease and breast imaging diagnosis. Facilities performing breast MRI should have the capacity to perform correlation with prior breast imaging examinations, directed breast ultrasound, and MRI-guided intervention. Alternatively, if these services are not available at the facility performing breast MRI, the facility should create a referral arrangement with a cooperating facility that can provide these services. If MRI-guided breast biopsy is performed, histopathologic results should be available to the interpreting physician as well as the procedural physician. The MRI biopsy facility should have the physician expertise to determine radiologic-pathologic concordance and the ability to report management recommendations in the biopsy report. For suspicious or indeterminate findings detected on breast MRI that are occult and/or unlikely to be seen on mammography and breast ultrasound, an MRI-guided biopsy should be performed. For further information, see the [ACR Practice Parameter for the Performance of Magnetic Resonance Imaging-Guided Breast Interventional Procedures](#) [68].

### IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for MRI of the breast should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the stated scope of practice requirements. (ACR Resolution 35, adopted in 2006 – revised in 2016, Resolution 12-b)

### IV. SPECIFICATIONS OF THE EXAMINATION

#### A. Patient Selection and Preparation

The physician responsible for the breast MRI should supervise patient selection and preparation. Patients should be screened for possible contraindications for MRI as discussed in section III. Patients suffering from anxiety or claustrophobia may require anxiolysis to achieve a successful examination (see the [ACR–SIR Practice Parameter for Minimal and/or Moderate Sedation/Analgesia](#) [69]). MRI bore constraints, the patient's size, and the patient's ability to remain in the prone position for the duration of the examination should be considered.

Recent evidence suggests that background parenchymal enhancement (BPE) and diagnostic performance of breast MRI are not significantly affected by menstrual cycle phase [70,71]. Consequently, for premenopausal women, menstrual cycle phase should not necessarily factor into breast MRI scheduling. Additionally, when clinically indicated, breast MRI may be performed in lactating patients, because MRI successfully detects cancers despite the elevated BPE associated with lactating breast tissue [72-74]. For guidance regarding the use of gadolinium-based contrast agents in lactating women, please see the [ACR Manual on Contrast Media](#) [59].

### IV. SPECIFICATIONS OF THE EXAMINATION

## B. Facility Requirements

Appropriate emergency equipment with medications must be immediately available to treat adverse reactions associated with administered medications, including gadolinium-based contrast agents. The equipment and medications should be monitored for inventory and drug expiration dates on a regular basis. The equipment, medications, and other emergency support must also be appropriate for the range of ages and sizes in the patient population. Facility staff should be trained in the use of emergency equipment and medications in accordance with the [ACR Manual on Contrast Media](#) [59].

## V. DOCUMENTATION

Reporting should be in accordance with the [ACR Practice Parameter for Communication of Diagnostic Imaging Findings](#) [75]. The report should follow the guidelines for terminology, including descriptions of lesion features and location, as published in the ACR BI-RADS® Lexicon for Breast MRI. Analysis of abnormalities on breast MRI ought to consider both morphologic and kinetic features of the abnormality. The BI-RADS assessment category should be included in the conclusion of the report [66].

## VI. EQUIPMENT SPECIFICATIONS

Equipment monitoring should be in accordance with the [ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance \(MR\) Imaging Equipment](#) including testing of the breast coil(s) by a Qualified Medical Physicist or Qualified Medical Scientist [76].

The MRI equipment specifications and performance must meet all state and federal requirements. The requirements include, but are not limited to, specifications of maximum static magnetic field strength, maximum rate of change of magnetic field strength (dB/dT), maximum radiofrequency power deposition (specific absorption rate), and maximum acoustic noise levels [66,77].

### Technical Guidelines

#### 1. Resolution, contrast, and field strength

Facilities performing contrast-enhanced breast MRI should meet [ACR Breast MRI Accreditation Program Requirements](#) [78]. The selection of field strength is a major technical decision. A 1.5T magnet has traditionally been considered a minimum technical recommendation because of the relationship between field strength and resolution. However, improvements in other components of the scanning process have resulted in improved scan quality at lower field strengths. High spatial and temporal resolutions are needed to detect and characterize small abnormalities on MRI. The slice thickness should be 3 mm or less, and in-plane pixel resolution should be 1 mm or less to minimize volume-averaging effects. Simultaneous bilateral high-resolution breast imaging should be performed. Gadolinium contrast enhancement is required for the evaluation of breast parenchyma and identification of abnormalities including breast cancer but is not necessary in the evaluation of implant integrity [79,80]. Gadolinium contrast should be administered as a bolus with a standard dose of 0.1 mmol/kg followed by a saline flush of at least 10 mL.

#### 2. Pulse sequences

Comprehensive breast MRI scans should include a T2-weighted/bright fluid sequence and a multiphase pre- and postcontrast T1-weighted series. Optimized contrast between the tumor and surrounding tissue is important. When high-resolution images are being obtained, fat-suppressed sequences help to more easily identify contrast enhancement while preserving the signal-to-noise ratio. Sole reliance on subtraction imaging for the assessment of enhancement may be compromised by misregistration due to patient motion; use of fat suppression is recommended on sequences used to assess contrast enhancement. Often protocols incorporate both fat suppression and subtraction. Motion correction may be helpful in reducing artifacts encountered with image subtraction. A single non-fat-suppressed, precontrast T1-weighted sequence should also be considered to facilitate the characterization of fat-containing breast lesions.

Specific imaging parameters (eg, repetition time and echo time, etc) and types of T2- and T1-weighted pulse sequences (eg, short tau inversion recovery, conventional spin echo, gradient echo, etc) should be determined at the facility or programmatic level.

### 3. Scan time for T1-weighted sequences

A precontrast scan is obtained. Scan time in relation to contrast injection is extremely important for lesion identification and characterization. Kinetic information should be reported and based on enhancement data determined at specified postcontrast intervals separated by 4 minutes or less for the T1-postcontrast series. Imaging sites should have adequately short temporal resolution for accurate lesion identification, characterization, and BPE assessment, ideally performed at 90 seconds postcontrast administration [81]. Computer-aided evaluation (CAE) software is commonly used at image interpretation to perform postprocessing and display kinetic information.

### 4. Positioning

Examinations should be performed with a dedicated bilateral breast MRI coil. Patients should be positioned within the coil to ensure that the field-of-view includes the entire bilateral breasts, from the axillae to the inframammary folds. Skin folds should be minimized. If feasible, the nipples should be positioned to symmetrically point down to the ground.

## VII. SAFETY GUIDELINES

See the [ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#), the [ACR Manual on Contrast Media](#), and the [ACR Manual on MR Safety](#) [59,66,67].

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis [53,54,82,83].

## VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on QC & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (<https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement>).

Examinations should be systematically reviewed and evaluated as part of the overall quality improvement program at the facility. Monitoring should evaluate the accuracy of interpretation as well as the appropriateness of indications for the examinations. Complications and adverse events or activities that may have the potential for sentinel events must be monitored, analyzed, reported, and periodically reviewed to identify opportunities to improve patient care. These data should be collected in a manner that complies with statutory and regulatory peer-review procedures to ensure the confidentiality of the peer-review process.

Each facility should establish and maintain a medical outcome audit program to follow up positive assessments and to correlate pathology results with the interpreting physician's findings. (If the facility does not perform MRI-guided intervention, it should have access to correlative pathology results from the accredited facility with which it has a referral arrangement.) As above, such audits should encompass interpretation accuracy and examination appropriateness. Facilities should use the BI-RADS final assessment codes and terminology for reporting and tracking outcomes. The BI-RADS Atlas contains guidance on monitoring outcomes and conducting audits [53]. Summary statistics and comparisons generated for each physician and for each facility should be reviewed annually by the lead interpreting physician.

For further information, please see the [ACR Breast MRI Accreditation Program Requirements](#) [78].

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## **REFERENCES**

1. Berg WA, Zhang Z, Lehrer D, et al. Detection of breast cancer with addition of annual screening ultrasound or a single screening MRI to mammography in women with elevated breast cancer risk. *JAMA : the journal of the American Medical Association* 2012;307:1394-404.
2. Kriege M, Brekelmans CT, Boetes C, et al. Efficacy of MRI and mammography for breast-cancer screening in women with a familial or genetic predisposition. *The New England journal of medicine* 2004;351:427-37.
3. Kuhl C, Weigel S, Schrading S, et al. Prospective multicenter cohort study to refine management recommendations for women at elevated familial risk of breast cancer: the EVA trial. *Journal of clinical oncology : official journal of the American Society of Clinical Oncology* 2010;28:1450-7.
4. Kuhl CK, Schrading S, Leutner CC, et al. Mammography, breast ultrasound, and magnetic resonance imaging for surveillance of women at high familial risk for breast cancer. *Journal of clinical oncology : official journal of the American Society of Clinical Oncology* 2005;23:8469-76.
5. Leach MO, Boggis CR, Dixon AK, et al. Screening with magnetic resonance imaging and mammography of a UK population at high familial risk of breast cancer: a prospective multicentre cohort study (MARIBS). *Lancet* 2005;365:1769-78.
6. Lehman CD, Blume JD, Weatherall P, et al. Screening women at high risk for breast cancer with mammography and magnetic resonance imaging. *Cancer* 2005;103:1898-905.
7. Lehman CD, Isaacs C, Schnall MD, et al. Cancer yield of mammography, MR, and US in high-risk women: prospective multi-institution breast cancer screening study. *Radiology* 2007;244:381-8.
8. Morris EA, Liberman L, Ballon DJ, et al. MRI of occult breast carcinoma in a high-risk population. *AJR. American journal of roentgenology* 2003;181:619-26.
9. Raikhlin A, Curpen B, Warner E, Betel C, Wright B, Jong R. Breast MRI as an adjunct to mammography for

breast cancer screening in high-risk patients: retrospective review. *AJR. American journal of roentgenology* 2015;204:889-97.

10. Sardanelli F, Podo F, Santoro F, et al. Multicenter surveillance of women at high genetic breast cancer risk using mammography, ultrasonography, and contrast-enhanced magnetic resonance imaging (the high breast cancer risk italian 1 study): final results. *Investigative radiology* 2011;46:94-105.
11. Saslow D, Boetes C, Burke W, et al. American Cancer Society guidelines for breast screening with MRI as an adjunct to mammography. *CA: a cancer journal for clinicians* 2007;57:75-89.
12. Warner E, Plewes DB, Hill KA, et al. Surveillance of BRCA1 and BRCA2 mutation carriers with magnetic resonance imaging, ultrasound, mammography, and clinical breast examination. *JAMA : the journal of the American Medical Association* 2004;292:1317-25.
13. Weinstein SP, Localio AR, Conant EF, Rosen M, Thomas KM, Schnall MD. Multimodality screening of high-risk women: a prospective cohort study. *Journal of clinical oncology : official journal of the American Society of Clinical Oncology* 2009;27:6124-8.
14. Smith RA, Andrews KS, Brooks D, et al. Cancer screening in the United States, 2019: A review of current American Cancer Society guidelines and current issues in cancer screening. *CA: a cancer journal for clinicians* 2019;69:184-210.
15. Cho N, Han W, Han BK, et al. Breast Cancer Screening With Mammography Plus Ultrasonography or Magnetic Resonance Imaging in Women 50 Years or Younger at Diagnosis and Treated With Breast Conservation Therapy. *JAMA Oncol* 2017;3:1495-502.
16. Gweon HM, Cho N, Han W, et al. Breast MR imaging screening in women with a history of breast conservation therapy. *Radiology* 2014;272:366-73.
17. Lehman CD, Lee JM, DeMartini WB, et al. Screening MRI in Women With a Personal History of Breast Cancer. *Journal of the National Cancer Institute* 2016;108.
18. Bakker MF, de Lange SV, Pijnappel RM, et al. Supplemental MRI Screening for Women with Extremely Dense Breast Tissue. *The New England journal of medicine* 2019;381:2091-102.
19. Veenhuizen SGA, de Lange SV, Bakker MF, et al. Supplemental Breast MRI for Women with Extremely Dense Breasts: Results of the Second Screening Round of the DENSE Trial. *Radiology* 2021;299:278-86.
20. Monticciolo DL, Malak SF, Friedewald SM, et al. Breast Cancer Screening Recommendations Inclusive of All Women at Average Risk: Update from the ACR and Society of Breast Imaging. *Journal of the American College of Radiology : JACR* 2021;18:1280-88.
21. Barco I, Chabrera C, Garcia-Fernandez A, et al. Magnetic resonance imaging in the preoperative setting for breast cancer patients with undetected additional disease. *European journal of radiology* 2016;85:1786-93.
22. Berg WA, Gutierrez L, NessAiver MS, et al. Diagnostic accuracy of mammography, clinical examination, US, and MR imaging in preoperative assessment of breast cancer. *Radiology* 2004;233:830-49.
23. Braun M, Polcher M, Schrading S, et al. Influence of preoperative MRI on the surgical management of patients with operable breast cancer. *Breast cancer research and treatment* 2008;111:179-87.
24. Chudgar AV, Conant EF, Weinstein SP, et al. Assessment of disease extent on contrast-enhanced MRI in breast cancer detected at digital breast tomosynthesis versus digital mammography alone. *Clin Radiol* 2017;72:573-79.
25. DeBald M, Abramian A, Nemes L, et al. Who may benefit from preoperative breast MRI? A single-center analysis of 1102 consecutive patients with primary breast cancer. *Breast cancer research and treatment* 2015;153:531-7.
26. Elmi A, Conant EF, Kozlov A, et al. Preoperative breast MR imaging in newly diagnosed breast cancer: Comparison of outcomes based on mammographic modality, breast density and breast parenchymal enhancement. *Clin Imaging* 2021;70:18-24.
27. Kim JY, Cho N, Koo HR, et al. Unilateral breast cancer: screening of contralateral breast by using preoperative MR imaging reduces incidence of metachronous cancer. *Radiology* 2013;267:57-66.
28. Lehman CD, Blume JD, Thickman D, et al. Added cancer yield of MRI in screening the contralateral breast of women recently diagnosed with breast cancer: results from the International Breast Magnetic Resonance Consortium (IBMC) trial. *Journal of surgical oncology* 2005;92:9-15; discussion 15-6.
29. Lehman CD, Gatsonis C, Kuhl CK, et al. MRI evaluation of the contralateral breast in women with recently diagnosed breast cancer. *The New England journal of medicine* 2007;356:1295-303.
30. Liberman L, Morris EA, Kim CM, et al. MR imaging findings in the contralateral breast of women with recently diagnosed breast cancer. *AJR. American journal of roentgenology* 2003;180:333-41.



31. Chou SS, Romanoff J, Lehman CD, et al. Preoperative Breast MRI for Newly Diagnosed Ductal Carcinoma in Situ: Imaging Features and Performance in a Multicenter Setting (ECOG-ACRIN E4112 Trial). *Radiology* 2021;301:66-77.
32. Kazama T, Nakamura S, Doi O, Suzuki K, Hirose M, Ito H. Prospective evaluation of pectoralis muscle invasion of breast cancer by MR imaging. *Breast Cancer* 2005;12:312-6.
33. Morris EA, Schwartz LH, Drotman MB, et al. Evaluation of pectoralis major muscle in patients with posterior breast tumors on breast MR images: early experience. *Radiology* 2000;214:67-72.
34. Myers KS, Stern E, Ambinder EB, Oluyemi ET. Breast cancer abutting the pectoralis major muscle on breast MRI: what are the clinical implications? *Br J Radiol* 2021;94:20201202.
35. Marinovich ML, Houssami N, Macaskill P, et al. Meta-analysis of magnetic resonance imaging in detecting residual breast cancer after neoadjuvant therapy. *Journal of the National Cancer Institute* 2013;105:321-33.
36. Scheel JR, Kim E, Partridge SC, et al. MRI, Clinical Examination, and Mammography for Preoperative Assessment of Residual Disease and Pathologic Complete Response After Neoadjuvant Chemotherapy for Breast Cancer: ACRIN 6657 Trial. *AJR. American journal of roentgenology* 2018;210:1376-85.
37. Buchanan CL, Morris EA, Dorn PL, Borgen PI, Van Zee KJ. Utility of breast magnetic resonance imaging in patients with occult primary breast cancer. *Annals of surgical oncology* 2005;12:1045-53.
38. Obdeijn IM, Brouwers-Kuyper EM, Tilanus-Linthorst MM, Wiggers T, Oudkerk M. MR imaging-guided sonography followed by fine-needle aspiration cytology in occult carcinoma of the breast. *AJR. American journal of roentgenology* 2000;174:1079-84.
39. Olson JA, Jr., Morris EA, Van Zee KJ, Linehan DC, Borgen PI. Magnetic resonance imaging facilitates breast conservation for occult breast cancer. *Annals of surgical oncology* 2000;7:411-5.
40. Orel SG, Weinstein SP, Schnall MD, et al. Breast MR imaging in patients with axillary node metastases and unknown primary malignancy. *Radiology* 1999;212:543-9.
41. Berger N, Luparia A, Di Leo G, et al. Diagnostic Performance of MRI Versus Galactography in Women With Pathologic Nipple Discharge: A Systematic Review and Meta-Analysis. *AJR. American journal of roentgenology* 2017;209:465-71.
42. Boisserie-Lacroix M, Doutriaux-Dumoulin I, Chopier J, et al. Diagnostic accuracy of breast MRI for patients with suspicious nipple discharge and negative mammography and ultrasound: a prospective study. *Eur Radiol* 2021;31:7783-91.
43. Amitai Y, Scaranelo A, Menes TS, et al. Can breast MRI accurately exclude malignancy in mammographic architectural distortion? *Eur Radiol* 2020;30:2751-60.
44. Giess CS, Chikarmane SA, Sippo DA, Birdwell RL. Clinical Utility of Breast MRI in the Diagnosis of Malignancy After Inconclusive or Equivocal Mammographic Diagnostic Evaluation. *AJR. American journal of roentgenology* 2017:1-8.
45. Lee CH, Smith RC, Levine JA, Troiano RN, Tocino I. Clinical usefulness of MR imaging of the breast in the evaluation of the problematic mammogram. *AJR. American journal of roentgenology* 1999;173:1323-9.
46. Moy L, Elias K, Patel V, et al. Is breast MRI helpful in the evaluation of inconclusive mammographic findings? *AJR. American journal of roentgenology* 2009;193:986-93.
47. Oztekin PS, Kosar PN. Magnetic resonance imaging of the breast as a problem-solving method: to be or not to be? *The breast journal* 2014;20:622-31.
48. Sardanelli F, Melani E, Ottonello C, et al. Magnetic resonance imaging of the breast in characterizing positive or uncertain mammographic findings. *Cancer detection and prevention* 1998;22:39-42.
49. Spick C, Szolar DH, Preidler KW, Tillich M, Reittner P, Baltzer PA. Breast MRI used as a problem-solving tool reliably excludes malignancy. *European journal of radiology* 2015;84:61-4.
50. Yau EJ, Gutierrez RL, DeMartini WB, Eby PR, Peacock S, Lehman CD. The utility of breast MRI as a problem-solving tool. *The breast journal* 2011;17:273-80.
51. Comstock CE, Gatsonis C, Newstead GM, et al. Comparison of Abbreviated Breast MRI vs Digital Breast Tomosynthesis for Breast Cancer Detection Among Women With Dense Breasts Undergoing Screening. *JAMA : the journal of the American Medical Association* 2020;323:746-56.
52. D'Orsi CJ, Sickles EA, Mendelson EB, Morris EA et al. *ACR BI-RADS® Atlas, Breast Imaging Reporting and Data System*. Reston, VA: American College of Radiology; 2013.
53. Grimm LJ, Soo MS, Yoon S, Kim C, Ghate SV, Johnson KS. Abbreviated screening protocol for breast MRI: a feasibility study. *Academic radiology* 2015;22:1157-62.
54. Harvey SC, Di Carlo PA, Lee B, Obadina E, Sippo D, Mullen L. An Abbreviated Protocol for High-Risk

- Screening Breast MRI Saves Time and Resources. *Journal of the American College of Radiology* : JACR 2016;13:374-80.
55. Kuhl CK, Schrading S, Strobel K, Schild HH, Hilgers RD, Bieling HB. Abbreviated breast magnetic resonance imaging (MRI): first postcontrast subtracted images and maximum-intensity projection—a novel approach to breast cancer screening with MRI. *Journal of clinical oncology : official journal of the American Society of Clinical Oncology* 2014;32:2304-10.
  56. Kwon MR, Choi JS, Won H, et al. Breast Cancer Screening with Abbreviated Breast MRI: 3-year Outcome Analysis. *Radiology* 2021;299:73-83.
  57. Shellock FG, Spinazzi A. MRI safety update 2008: part 2, screening patients for MRI. *AJR. American journal of roentgenology* 2008;191:1140-9.
  58. Partridge SC, Nissan N, Rahbar H, Kitsch AE, Sigmund EE. Diffusion-weighted breast MRI: Clinical applications and emerging techniques. *Journal of magnetic resonance imaging : JMRI* 2017;45:337-55.
  59. American College of Radiology. ACR manual on contrast media. Available at: [https://www.acr.org/-/media/ACR/Files/Clinical-Resources/Contrast\\_Media.pdf](https://www.acr.org/-/media/ACR/Files/Clinical-Resources/Contrast_Media.pdf). Accessed September 20, 2022.
  60. Kanal E, Shellock FG. Aneurysm clips: effects of long-term and multiple exposures to a 1.5-T MR system. *Radiology* 1999;210:563-5.
  61. Kanal E, Shellock FG, Lewin JS. Aneurysm clip testing for ferromagnetic properties: clip variability issues. *Radiology* 1996;200:576-8.
  62. Shellock FG. *Magnetic Resonance Procedures: Health Effects and Safety*. Boca Raton, Fla: CRC Press; 2000.
  63. Bussmann S, Luechinger R, Froehlich JM, et al. Safety of intrauterine devices in MRI. *PloS one* 2018;13:e0204220.
  64. Elster AD, Link KM, Carr JJ. Patient screening prior to MR imaging: a practical approach synthesized from protocols at 15 U. S. medical centers. *AJR. American journal of roentgenology* 1994;162:195-9.
  65. Shellock FG. *The Reference Manual for Magnetic Resonance Safety. Implants and Devices*. Los Angeles, Calif: Biomedical Research Publishing Company; 2010.
  66. American College of Radiology. ACR manual on MR safety. Available at: <https://www.acr.org/-/media/ACR/Files/Radiology-Safety/MR-Safety/Manual-on-MR-Safety.pdf>. Accessed January 7, 2022.
  67. American College of Radiology. ACR practice parameter for performing and interpreting magnetic resonance imaging (MRI) Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/MR-Perf-Interpret.pdf>. Accessed January 7, 2022.
  68. American College of Radiology. ACR practice parameter for the performance of magnetic resonance imaging-guided breast interventional procedures. Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/MR-Guided-Breast.pdf>. Accessed May 5, 2022.
  69. American College of Radiology. ACR–SIR practice parameter for minimal and/or moderate sedation/analgesia Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Sed-Analgesia.pdf>. Accessed January 7, 2022.
  70. Dontchos BN, Rahbar H, Partridge SC, Lehman CD, DeMartini WB. Influence of Menstrual Cycle Timing on Screening Breast MRI Background Parenchymal Enhancement and Diagnostic Performance in Premenopausal Women. *J Breast Imaging* 2019;1:205-11.
  71. Lee CH, Bryce Y, Zheng J, et al. Outcome of Screening MRI in Premenopausal Women as a Function of the Week of the Menstrual Cycle. *AJR. American journal of roentgenology* 2020;214:1175-81.
  72. Espinosa LA, Daniel BL, Vidarsson L, Zakhour M, Ikeda DM, Herfkens RJ. The lactating breast: contrast-enhanced MR imaging of normal tissue and cancer. *Radiology* 2005;237:429-36.
  73. Nissan N, Allweis T, Menes T, et al. Breast MRI during lactation: effects on tumor conspicuity using dynamic contrast-enhanced (DCE) in comparison with diffusion tensor imaging (DTI) parametric maps. *Eur Radiol* 2020;30:767-77.
  74. Taron J, Fleischer S, Preibsch H, Nikolaou K, Gruber I, Bahrs S. Background parenchymal enhancement in pregnancy-associated breast cancer: a hindrance to diagnosis? *Eur Radiol* 2019;29:1187-93.
  75. American College of Radiology. ACR practice parameter for communication of diagnostic imaging findings Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CommunicationDiag.pdf>. Accessed January 7, 2022.
  76. American College of Radiology. ACR–AAPM technical standard for diagnostic–medical physics performance monitoring of magnetic resonance (MR) imaging equipment Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/MR-Equip.pdf>. Accessed January 7, 2022.

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77. Helms DL, et al. *Breast MRI: fundamentals and technical aspects*. New York, NY: Springer; 2008.
78. American College of Radiology. ACR breast MRI accreditation program requirements. Available at: <https://accreditationsupport.acr.org/support/solutions/articles/11000063266-complete-accreditation-information-breast-mri>. Accessed April 14, 2022.
79. Mann RM, Cho N, Moy L. Breast MRI: State of the Art. *Radiology* 2019;292:520-36.
80. Seiler SJ, Sharma PB, Hayes JC, et al. Multimodality Imaging-based Evaluation of Single-Lumen Silicone Breast Implants for Rupture. *Radiographics : a review publication of the Radiological Society of North America, Inc* 2017;37:366-82.
81. Morris EA, Comstock CE, Lee CH, et al. *ACR BI-RADS® Magnetic Resonance Imaging. In: ACR BI-RADS® Atlas, Breast Imaging Reporting and Data System*. Reston, VA: American College of Radiology; 2013.
82. Shellock FG. Magnetic resonance safety update 2002: implants and devices. *Journal of magnetic resonance imaging : JMRI* 2002;16:485-96.
83. Shellock FG, Crues JV. MR procedures: biologic effects, safety, and patient care. *Radiology* 2004;232:635-52.

\*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised, or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

#### Development Chronology for this Practice Parameter 2004 (Resolution 11)

Amended 2006 (Resolution 35)

Revised 2008 (Resolution 25)

Revised 2013 (Resolution 12)

Amended 2014 (Resolution 39)

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