Mary Perrine, RT (NM) (MRI)
Chief Breast MRI Technologist
Fairfax Radiological Consultants
Fairfax, VA

CHAPTER THREE

Breast MRI

After completing this chapter, the reader will be able to:

- **List the indications for breast MRI**
- **Explain normal vs abnormal findings**
- **Describe breast anatomy**
- **Appropriately position patient for breast MRI and MRI-guided biopsy**
- **Adequately prepare patient and room for biopsy**

Improvements in diagnostic imaging have increased the ability for early detection of breast cancer in recent years. Breast cancer is the most frequently occurring cancer and the second leading cause of death in U.S. women. With early detection advancements, the five-year survival rate for breast cancer has risen from 75% in 1975-1977 to 89% in 1996-2004.[1]

Breast MRI (**BMRI**) plays a major role in the early diagnosis of breast cancer, as well as defining the extent of tumor spread. It provides the ability to detect cancers not seen by mammography or ultrasound. The sensitivity for breast MRI in detecting breast cancer ranges from 77 to 100%. This high rate of sensitivity allows us to see everything within the breast, not just cancerous lesions, which could lead to the reporting of false negatives, such as ductal carcinoma in-situ, invasive lobular carcinomas, and rarely some invasive ductal carcinomas.

The drawback of this exemplar **sensitivity** is the varying range of **specificity**. As with any diagnostic study, there is the potential for **false positives**, such as fibroadenomas, fibrocystic

POINTS FOR PRACTICE

1. What is the difference between specificity and sensitivity of breast MRI?
2. What groups should receive high-risk screening with BMRI?
3. Describe the typical breast MR scan protocol.
4. In what plane should BMRI be performed?
5. What is background enhancement? Is it clinically significant?
6. What is fibrocystic change, and why can it be difficult to differentiate between this and malignancy? When is the preferred time during the menstrual cycle for women to be scanned?
7. What is a kinetic curve, and what can it tell us about lesion enhancement?
8. When is an MRI-guided biopsy indicated, and what type of scan protocol should be used?

changes, hyperplasia, adenosis, inflammatory changes, post-surgical changes, high-risk lesions, lobular carcinoma in-situ and atypia.

MRI vs Mammography

It is important to note that while BMRI is extremely valuable for the early detection of breast cancer, it is not a replacement for mammography. Mammography remains the imaging of choice due to its ability to detect architectural changes and calcifications and cost effectiveness.

INDICATIONS FOR BMRI

High-risk Screening

One of the earliest indications for MR breast imaging was for evaluation of silicone implant integrity. However, high-risk screening has also become one of the primary reasons for BMRI. The American Cancer Society recommends BMRI for:[2]

- women who are known to have the **BRCA mutation**
- women with a first-degree relative (mother, sister, daughter) diagnosed with breast cancer under the age of 40
- a lifetime breast cancer risk of ≥20%
- a history of radiation therapy to the chest between ages 10-30
- other genetic syndromes

Pre-operative Planning: Extent of Tumor

Pre-operative planning is an essential tool in the treatment of breast cancer. The extent of biopsy-proven cancers shown by BMRI greatly assists surgeons and oncologists in determining a treatment plan for cancer patients. Patients with **multifocal** cancers (cancers with multiple lesions in the same quadrant) can still be candidates for breast conservation surgery. Patients with **multicentric** tumors (tumors in multiple quadrants) can sometimes only be treated with a more extensive surgery. Pre-operative evaluation is also a useful tool in determining the extent of axillary lymph node involvement (Figure 18).

Contralateral Breast

Breast MRI is a very useful tool in evaluating the **contralateral** breast. Studies have shown that 3-5% of women with breast cancer will develop cancer in their contralateral breast in their lifetime.[3] It is, of course, preferable to treat both breasts at the same time if a contralateral cancer is detected. Under these circumstances, the patient may become a candidate for BRCA testing. Carriers of one of the two BRCA genes (breast cancer genes) have a higher risk of developing breast and ovarian cancers.

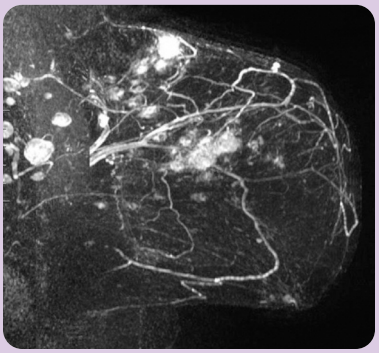


Figure 18. Extent of tumor involvement.

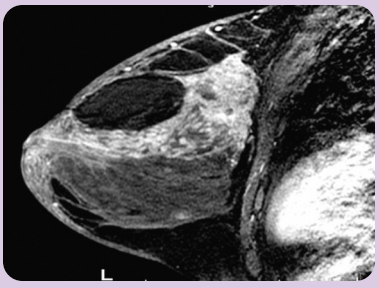
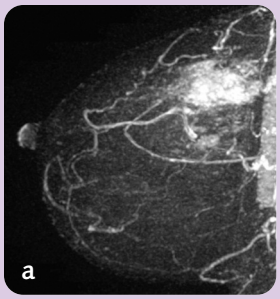


Figure 19. Post-surgical seroma with residual cancer.



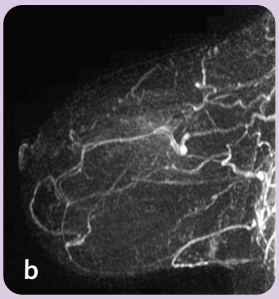
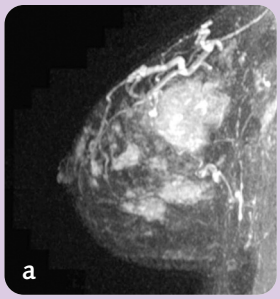


Figure 20. Neoadjuvant chemotherapy. (a) Pre-therapy. (b) Post-therapy showing complete response.



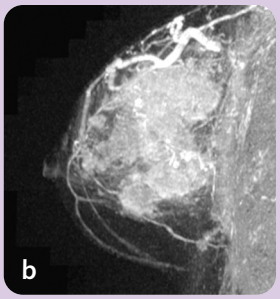


Figure 21. Neoadjuvant chemotherapy. (a) Pre-therapy. (b) Post-therapy showing no response.

Post-operative Evaluation

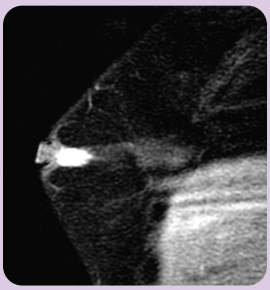
Post-operative evaluation is another indication for breast MRI. Patients with positive surgical margins and suspected residual cancer can greatly benefit from BMRI. Post-operative evaluation allows visualization of any residual cancer, the extent of the residual cancer, or any satellite lesions that may have been missed during the initial surgery (Figure 19).

Neoadjuvant Chemotherapy

BMRI can be used to evaluate the effectiveness of neoadjuvant chemotherapy, therapy given prior to surgery, to shrink the size of the tumor.

The patient is scanned at intervals after her initial diagnosis to evaluate the effect of the chemotherapy on the tumor. Often a complete pathologic response is seen. If the tumor is not responding to the treatment, or if the tumor has grown, the appropriate treatment can then be prescribed and the type of chemotherapy changed (Figures 20 and 21).

In some cases, a large cancer requiring mastectomy can be sufficiently reduced in size for the patient to undergo breast conservation surgery after her neoadjuvant chemotherapy.



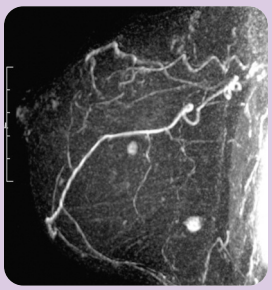


Figure 22. Axillary lymphadenopathy.

Biopsy-proven Axillary Carcinoma or Axillary Carcinoma with Unknown Primary Site

BMRI is considered one of the best tools for evaluating biopsy-proven axillary carcinoma in patients who have had a negative mammogram and sonogram (Figure 22).

Inconclusive Imaging and Asymmetry

Patients with inconclusive imaging, distortion on one view on mammogram not reproducible by ultrasound, or asymmetry, are good candidates for breast MRI. Breast density can obscure malignancies on mammography or

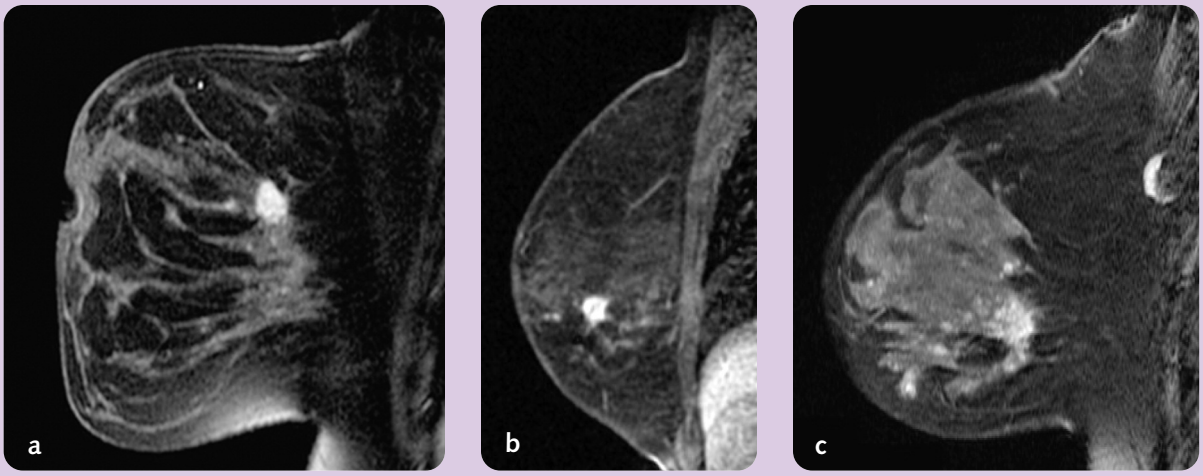


Figure 23. Inconclusive breast imaging. (a) Distortion one view only on mammography, normal US, MRI shows invasive lobular carcinoma. (b) Asymmetry on mammography, normal US, MRI shows invasive ductal carcinoma. (c) Diffuse calcifications on mammography, MRI shows DCIS.

ultrasound but does not affect the ability of BMRI to visualize suspicious lesions (Figure 23).

Silicone Implant Evaluation

Breast MRI still plays an important role in the evaluation of silicone implant integrity. These images are excellent for visualizing implant rupture, as well as differentiating between free silicone outside of the capsule and other anatomical structures.

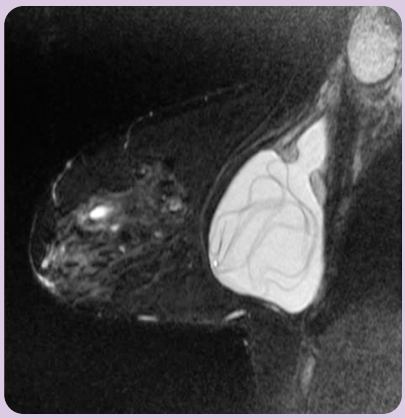


Figure 24. Silicone implant rupture.

An inversion recovery (**IR**) pulse sequence with water suppression is an excellent technique for determining silicone implant rupture. This sequence suppresses both fat and water, leaving only silicone visible on the image (Figure 24).

BREAST ANATOMY

A general knowledge of the anatomical structures within the breast and surrounding structures is important for obtaining quality images (Figure 25).

The breast itself consists of the skin and breast **parenchyma**. The skin contains hair follicles and glands. The breast is supported on the chest wall by bands of tissue called **Cooper's ligaments**.

In patients with various breast diseases, the skin can show important changes. Skin thickening can be an indicator of a pathological finding or can be associated with post-benign processes. Skin thickening can also be associated with inflammatory breast cancers, extensive primary invasive breast cancers,

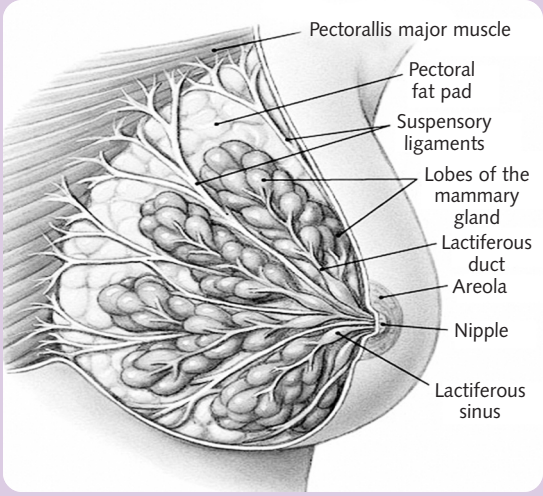


Figure 25. Breast anatomy. *Courtesy of Florida Community College of Jacksonville.*

Paget's disease of the nipple, and lymphomas. Benign causes of skin thickening can include mastitis, post-radiation changes, or edema from heart failure or lymphatic obstruction (Figure 26).

The breast parenchyma consists of milk-producing glands called **lobules** or **alveoli**. The parenchyma can be seen extending into the **axillary tail** and, in some patients, within the **axilla**. The inferior aspect of the breast is located at the **inframammary fold**.

The amount of breast parenchyma present determines the "density" of the breasts. On a mammogram a breast with predominate parenchymal tissue and little fat is considered extremely dense. One composed mainly of fat is considered to be "fatty replaced." On MRI, the breast can be easily assessed regardless of the amount of glandular tissue (Figure 27).

Milk ducts lead to the nipple from the glands. The breast has 20-40 lobules that drain into each duct, and fat surrounds the lobules and ducts.

At the tip of the breast is the nipple, which is surrounded by pigmented tissue known as the **areola**. Approximately 20 milk ducts empty into the nipple.

Difference in size between each breast is not uncommon; however, the nipples and areola are generally symmetric. While breast size and shape can vary with hormonal changes, the nipples should remain symmetric (Figure 28).

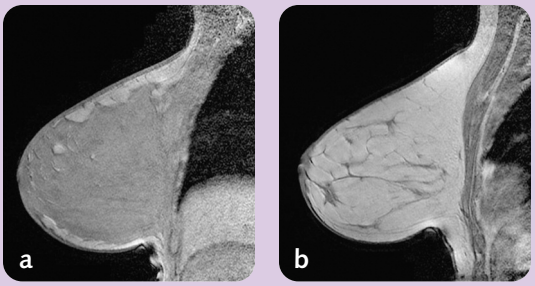


Figure 27. (a) Dense breast. (b) Fatty breast.

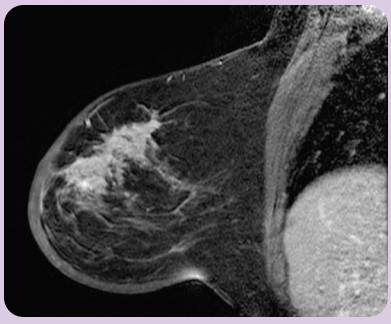


Figure 26. Skin thickening, post-contrast injection.

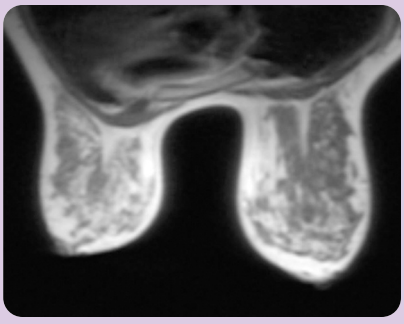


Figure 28. Normal asymmetrical breast.

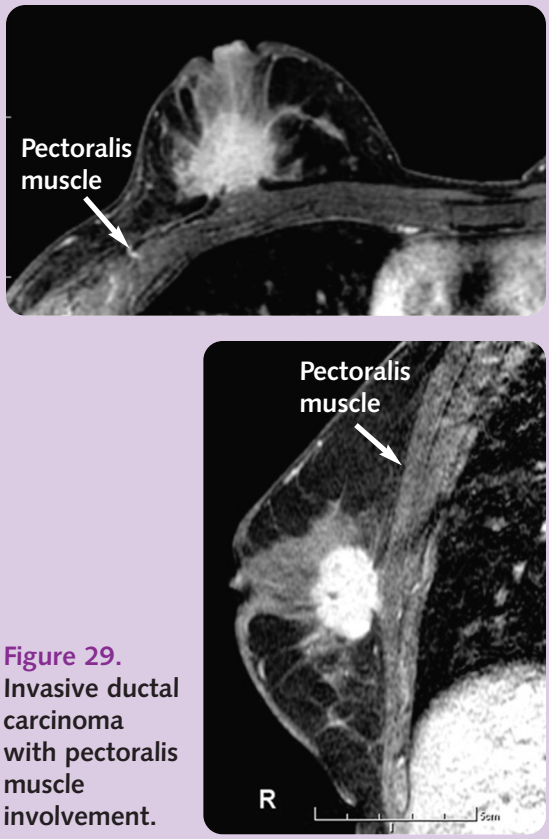


Figure 29. Invasive ductal carcinoma with pectoralis muscle involvement.

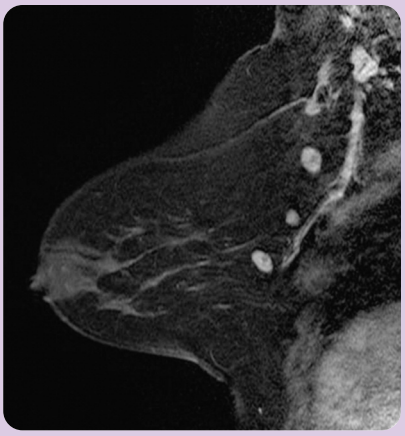


Figure 30. Lymph nodes.

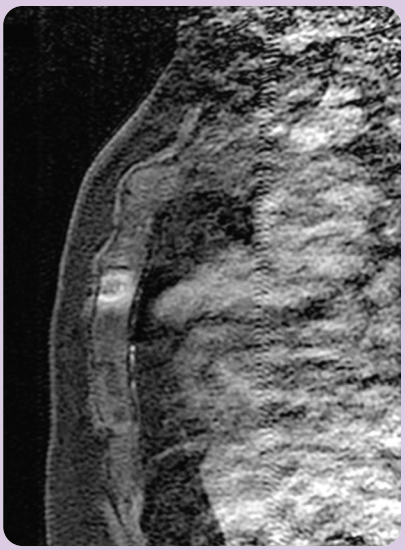


Figure 31. Post-contrast sternum with an enhancing metastatic lesion.

"Outside" the breast lie the pectoralis minor, the pectoralis major, and sternalis muscles. Even though these muscles are not considered to be part of the chest wall, a BMRI should include these muscles, as extensive cancers can have margins infiltrating into the pectoralis major muscle.

The chest wall includes the intercostal muscle, serratus anterior, and the ribs. Just like the muscles "outside" the breast, the chest wall is included in a BMRI evaluation (Figure 29).

Lymph nodes are commonly seen on breast MRI (Figure 30). They are highly vascular, usually present on BMRI with a fatty hilum, and are generally associated with a vessel. Lymph nodes should enhance homogeneously and often show wash-out of contrast.

There are between 15 and 40 axillary nodes that are responsible for most of the lymphatic drainage within the breast. On sagittal breast MRI images, lymph nodes located in the axillary tail give the appearance of grapes hanging on a vine. Intramammary lymph nodes are found within the breast parenchyma. They are most commonly seen in the upper, outer quadrant of the breast. Lymph nodes can also be seen along the internal mammary chain or within the supraclavicular location. This is

another route of drainage for the breast. These lymph nodes should always be assessed in known malignancy.

The sternum and ribs are also seen on BMRI. Post-radiation changes in the sternum generally appear as fatty replacement. Metastatic disease can be seen as high signal on T2 and as an increase in signal on the fat-saturated, post-contrast images (Figure 31).

IMAGING PROTOCOLS

Patient comfort is the foremost priority in achieving high-quality imaging. Patients referred for breast MRI are understandably anxious, and a sympathetic approach usually results in a technically better study.

Positioning in the Breast Coil

A dedicated breast coil is required to perform quality imaging as is an injection of contrast. Sites offering BMRI should also have the capacity for performing MR-guided breast biopsy, and the breast coil used should be able to provide both imaging and biopsy capability.

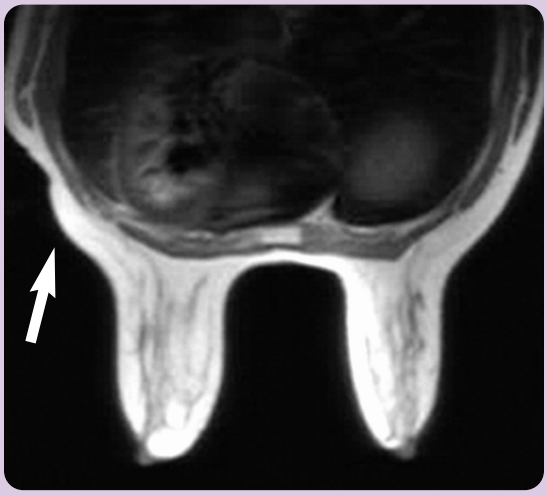


Figure 32. 3-plane localizer shows breast tissue that is not pulled into the coil (arrow).

It is extremely important to position the patient properly in the coil. Each breast should be centered within the coil and the tissue manually pulled into the coil, ensuring that no tissue is outside of the coil (Figure 32).

Routine Breast MR Imaging Protocol

The routine breast imaging protocol should include a 3-plane localizer (Table 2, page 47). This series should be done with relatively thin slices and is non-fat-suppressed with T2 weighting. This series is required to prescribe future series and to check for any incidental findings outside of the breast, including liver, lung and bone lesions, and chest wall abnormalities. Appropriate positioning of the patient in the coil also can be verified on the localizer.

T2-weighted fat suppression

Sagittal T2-weighted fat-suppressed or inversion recovery imaging is performed separately on each breast. Fluid and fluid-saturated tissues have brighter signal on T2-weighted images. By suppressing fat in this series, even tiny cysts or areas of edema can be visualized. These images should be done at no more than a 4 mm thickness. Care should be taken to include the axilla and sternum to evaluate lymph adenopathy and bony structures.

T2 fat-suppressed images can be susceptible to artifacts caused by the position of the patient in the coil, metallic foreign bodies such as biopsy markers and mediports, jewelry, and clothing. It is recommended that the patient remove earrings, necklaces, and clothing from the waist up and any other clothing containing metal. Care should be taken to screen for metallic implants and breast tissue expanders in patients preparing for breast reconstruction.

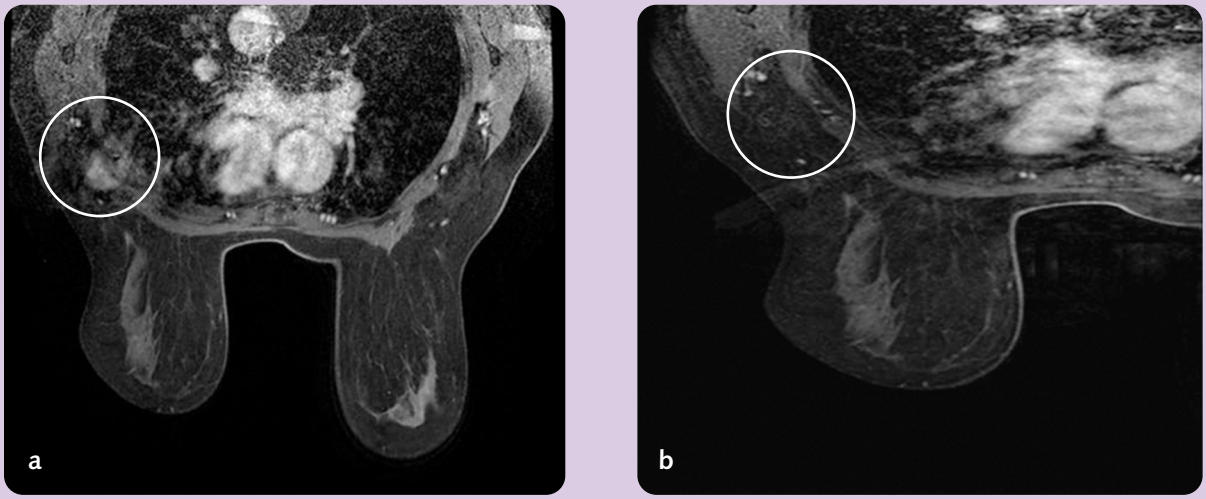


Figure 33. Phase artifact (a) Phase running right to left shows artifact from cardiac vessel in the axilla that gives the impression of a large abnormal axillary node. (b) Phase running anterior to posterior giving unobstructed view of axillary region with no abnormality.

T1-weighted 3D parallel imaging

A T1-weighted 3D parallel imaging sequence should be done of both breasts simultaneously to visualize the breast structures in detail.

A corresponding T1 3D with fat suppression is used pre- and post-contrast. Post-contrast imaging has specific requirements that include very thin slices, T1 weighting, fat suppression, and rapid wash-in/wash-out. This series is done dynamically with one series pre-contrast and four series post-contrast in less than two minutes per series. From these data a time intensity enhancement kinetic curve can be generated, a valuable tool in determining the characteristics of a specific lesion.

Breast MR imaging can be done in the sagittal plane to keep the field of view small, from 20 - 24 cm, and the resolution at its greatest, although some centers prefer to scan in the axial plane.

A T1 3D fat-suppressed series in the axial plane should be done after the dynamic post-

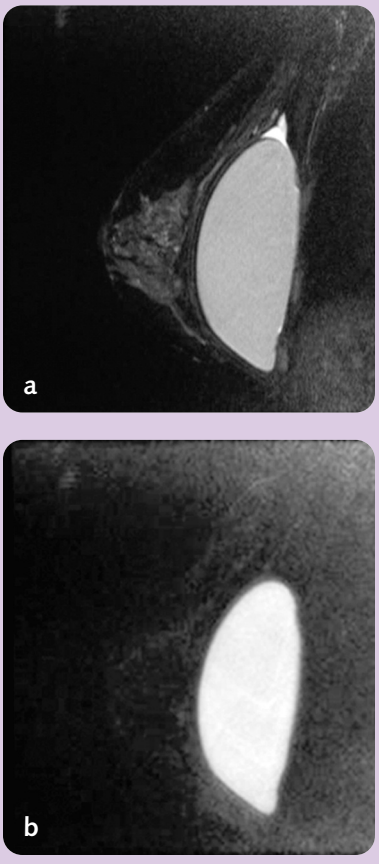


Figure 34. Silicone implant. (a) Inversion recovery. (b) Inversion recovery with water saturation.

contrast series. This series is an excellent tool for evaluating the axillary lymph nodes. Be aware of the direction of the phase artifact so that it does not obscure the axilla. Artifact thrown across the axilla from cardiac vessels may give the appearance of abnormal pathology (Figure 33).

Silicone Implant MRI Protocol

BMRI is an excellent tool for the evaluation of silicone implants (Table 3, page 47). An inversion recovery pulse sequence is used with a corresponding water-suppressed IR pulse sequence to suppress all tissue, leaving only the silicone visible. These sequences are done in both the sagittal and axial planes, allowing visualization of any silicone outside of the ruptured capsule, while suppressing any non-silicone fluid that might surround the implant (Figure 34).

A T1 non-fat-suppressed sagittal sequence determines the location of the implant, either subpectoral or subglandular. This protocol should also be used when evaluating double lumen implants.

Saline vs Silicone Implant Protocol

Rupture of a saline implant can be evaluated using the routine breast MR imaging protocol. A noticeable difference in the ruptured saline implant is usually seen on all series. In a 1.5 T field, the saline implant will be hyperintense on T2 fat-suppressed images; however, a silicone implant will be mostly dark because the frequency of fat and silicone are very close and when the fat suppresses, the silicone also suppresses. On an inversion recovery the silicone implant is visible, and the characteristics within the implant can be evaluated (Figure 35).

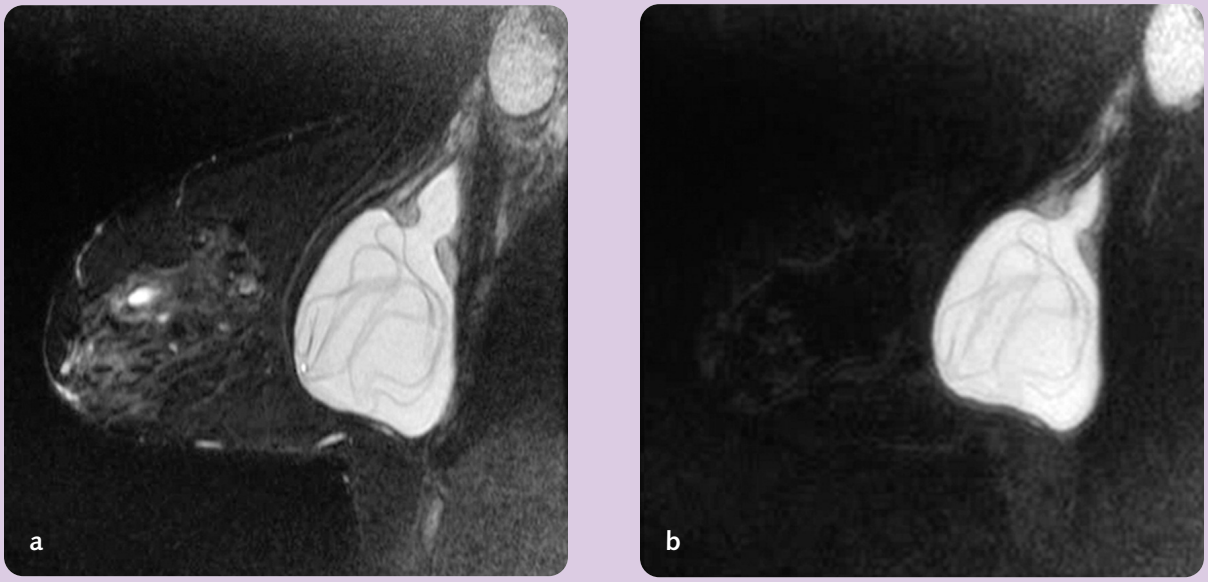


Figure 35. (a) Silicone implant rupture using inversion recovery. (b) Silicone implant rupture using water saturation inversion recovery. By doing a water-suppressed inversion recovery, you can confirm that the area in the superior part of the breast is extracapuslar silicone.

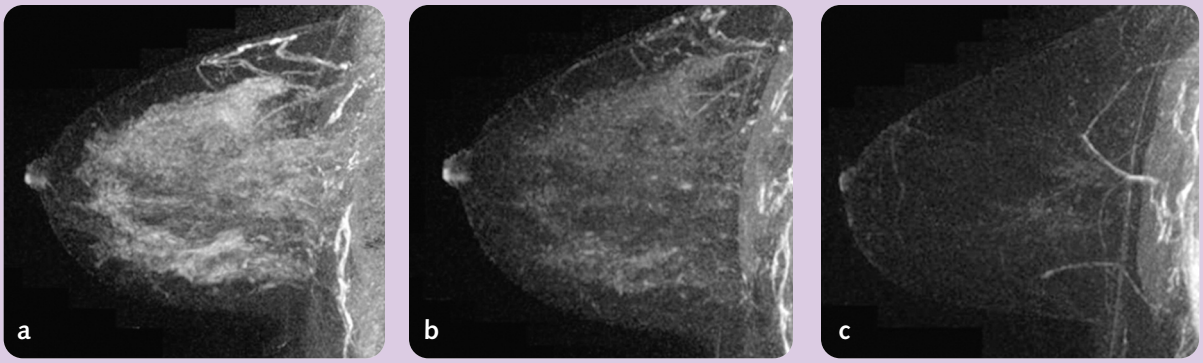


Figure 36. **Background enhancement. (a) Marked. (b) Moderate. (c) Minimal.**

In addition, if the patient presents with a mass or pain, it is important to do a dynamic contrast series to determine if a pathological process is the cause of the patient's symptoms.

MRI FINDINGS – BENIGN

Background Enhancement

Background enhancement is the normal enhancement within the breast parenchyma. It is not directly related to breast density. Background enhancement varies by patient and is affected by hormonal changes (menstrual cycle, hormone replacement therapy, and hormonal chemotherapy) and fibrocystic changes. Background enhancement can be classified as minimal, moderate, and marked (Figure 36).

Fibrocystic Change

Fibrocystic change refers to the change in cell characteristics of glandular tissue due to normal hormonal fluctuations during the menstrual cycle. Breast tenderness, pain, and lumpiness can be associated with fibrocystic change. Although it is a benign finding, it can be difficult to differentiate between fibrocystic change and malignant findings.

Dramatic changes can be seen when scanning women during different times of the menstrual cycle. The time in the patient's cycle should be noted to assist the radiologist in differentiating between normal fibrocystic change and malignancy. Imaging during Day 7-14 of the cycle is the preferred time frame in premenopausal women (Figure 37).

Cysts

Cysts are commonly seen on BMRI, and one or several cysts may be present. Simple cysts are hyperintense on T2-weighted images. If

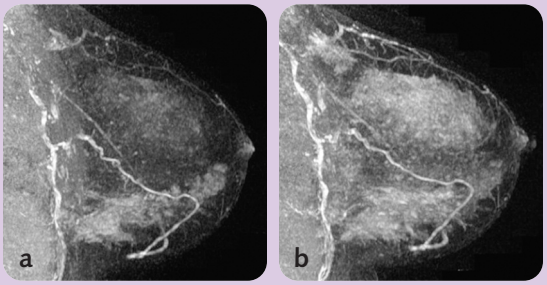
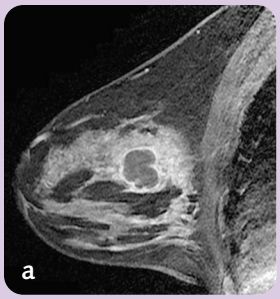


Figure 37. (a) **Day 10 of the menstrual cycle.** (b) **Day 28.**



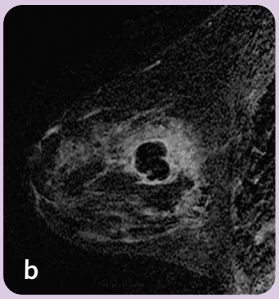


Figure 38. **Inflamed cyst.** (a) **Post-contrast.** (b) **Post-contrast subtraction.**

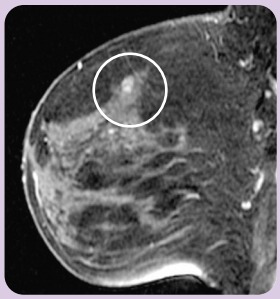


Figure 39. **Fibroadenoma.**

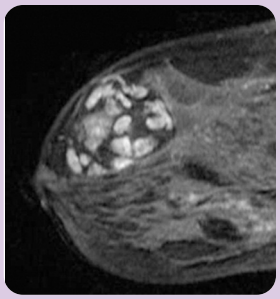


Figure 40. **Post-contrast hamartoma.**

cysts are complex and filled with **proteinaceous** material they will be hyperintense on T1-weighted images. Inflamed cysts will show rim enhancement post-contrast. Some larger cysts that become painful can be aspirated; often cysts resolve on their own (Figure 38).

Fibroadenomas

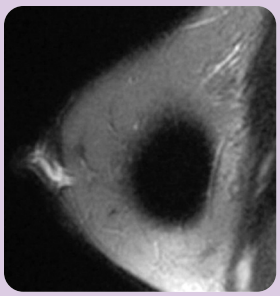
Fibroadenomas are common benign masses often seen on BMRI. They have smooth margins and are either round or oval in shape. They can vary in size, and a patient may have one or many. Fibroadenomas have varying contrast enhancement patterns depending on the cellularity of the lesion. Dark internal septations on T2-weighted and post-contrast images are common characteristics of a fibroadenoma (Figure 39). Fibroadenomas are often proven by biopsy.

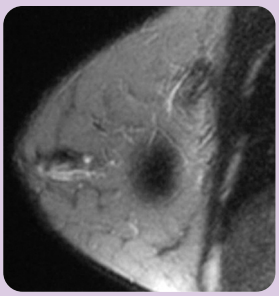
Hamartoma

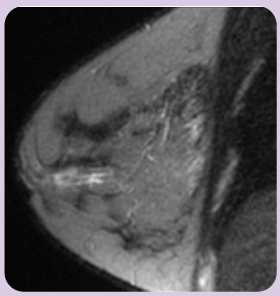
Hamartoma are also known as "breast within a breast." These rather rare benign lesions consist of fat, connective tissue, and glandular tissue. The parenchymal elements in a hamartoma will enhance more avidly than surrounding breast parenchyma. No treatment is required (Figure 40).

Papillomas

Papillomas are benign tumors that occur along the milk ducts and can cause benign nipple discharge. They may be hyperintense







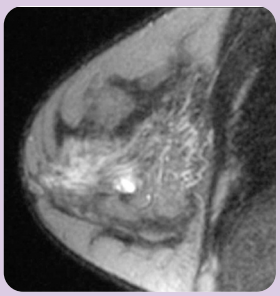


Figure 41. **Papillomas.**

on T2-weighted images and are often associated with a dilated duct. Papillomas may show rapid wash-out of contrast. They are biopsy-proven and are generally surgically excised (Figure 41).

Phylloides

Phylloides are generally benign and may look like a fibroadenoma. However, there are malignant phylloides that tend to demonstrate malignant features, including irregular shape and heterogeneous enhancement with contrast wash-out. Phylloides occur in the connective tissue of the breast. They are biopsy-proven and benign lesions require no treatment.

Lactation

Lactating breasts can be difficult to image on BMRI because of an overall marked increase in background enhancement and diffuse increase in T2 signal. It is best not to scan lactating women unless there is a cause for concern (Figure 42).

Mastitis

Mastitis is a result of a clogged milk duct and presents on BMRI as an overall increase in

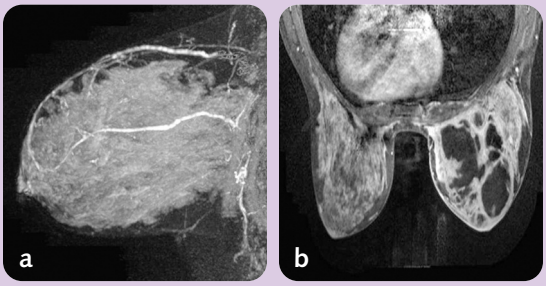


Figure 42. (a) **Lactating breast.** (b) **Post-contrast image of lactating woman with MRSA in the right breast.**

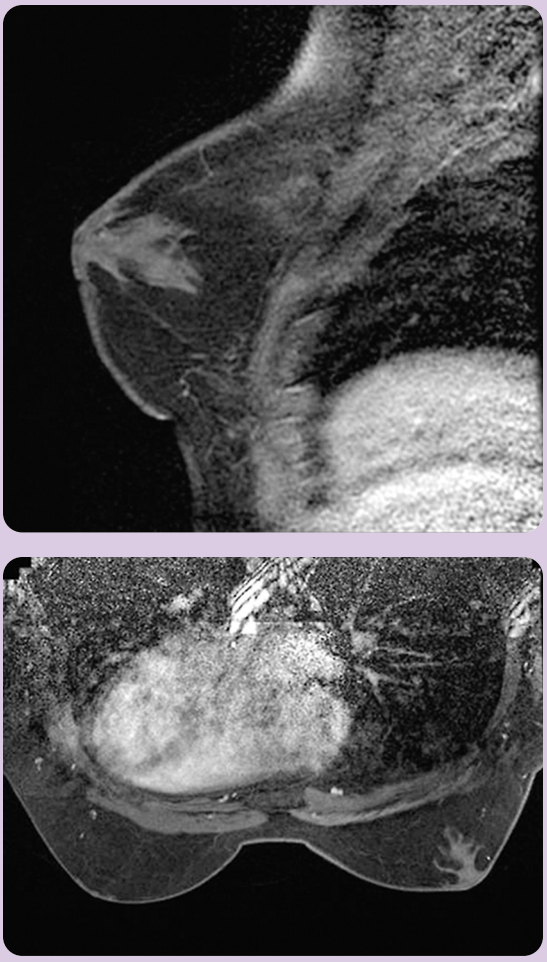


Figure 43. **Gynecomastia.**

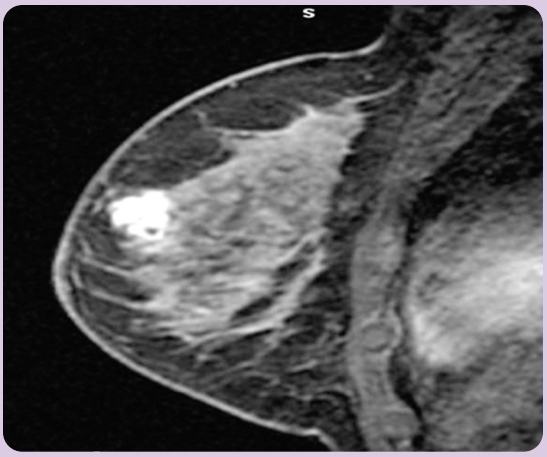


Figure 44. **Hematoma.**

enhancement in T2 signal in the affected breast. The skin may be thickened and lymph nodes enlarged. When the skin enhances in mastitis, the enhancement is homogeneous and progressive. An abscess appears as a T2 hyperintense or heterogeneous mass. Mastitis can be difficult to differentiate from inflammatory carcinoma because the symptoms are similar: pain, redness and swelling. Mastitis is usually treated with antibiotics.

Gynecomastia

Gynecomastia is tissue enlargement in the male breast, usually due to increase in estrogen or decrease in androgen hormones (Figure 43).

Post-operative Changes

Post-operative changes seen in MRI include seroma, hematoma, abscess, scar tissue, and fat necrosis.

A **hematoma** is a collection of blood that usually results from biopsy and resolves on its own. Hematoma is heterogeneous on all pulse sequences with peripheral enhancement. Abscess may be difficult to differentiate from hematoma due to the similarity in enhancement characteristics (Figure 44).

A **seroma** is a fluid-filled, surgical cavity. It may present for years after surgery. On post-contrast images, seromas may demonstrate rim enhancement (Figure 45).

Scar tissue can show progressive homogeneous enhancement. Fat necrosis can be diagnosed by fat signal intensity on fat-suppressed and non-fat-suppressed images, but in the initial stages when fat is not present, it may appear as a malignancy. Fat necrosis is often seen at the excisional biopsy or lumpectomy site (Figure 46).

Post-radiation Changes

Post-radiation changes may be seen for many years after treatment and consist of breast edema and skin thickening. Typically, overall background parenchymal enhancement decreases after radiation treatment. This decrease is most notable when the patient has moderate or marked background enhancement in the non-treated breast (Figure 47).

MRI FINDINGS – MALIGNANT

Non-mass-like Enhancement

Malignant tumors tend to have irregular shapes and irregular margins, heterogeneous enhancement, and wash-out kinetics. When not a discrete mass, the abnormal findings

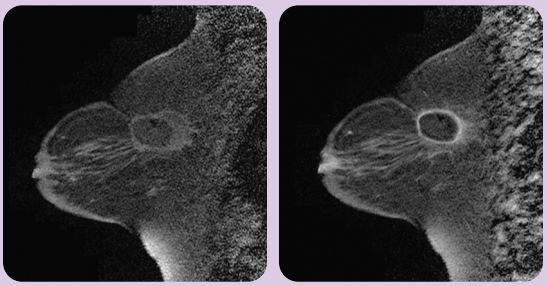


Figure 45. Seroma.

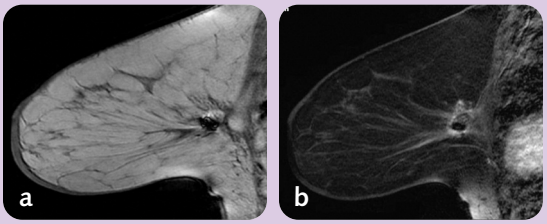


Figure 46. Scar tissue. (a) Non-fat suppression. (b) Post-contrast.

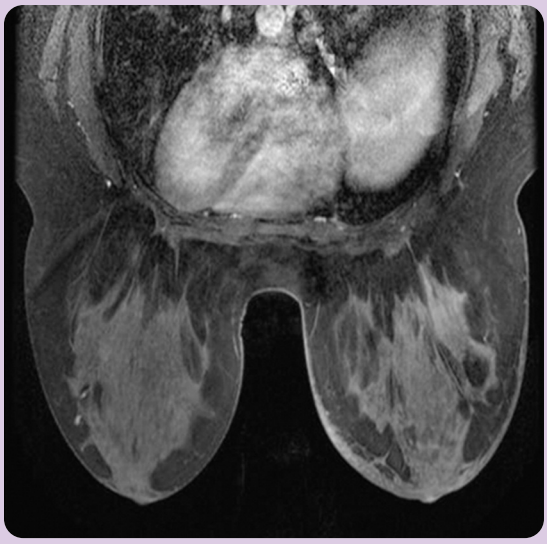


Figure 47. **Post-radiation changes seen post-contrast. Background parenchymal enhancement is decreased on the left breast.**

associated with malignancy are **termed non-mass-like enhancement** (**NMLE**). NMLE in malignancy may have a segmental, linear, or ductal distribution. NMLE can have a clumped or heterogeneous morphology. NMLE can be regional, multifocal, with more than one cancer in the same quadrant, or multicentric, with lesions seen in more than one quadrant of the breast (Figure 48).

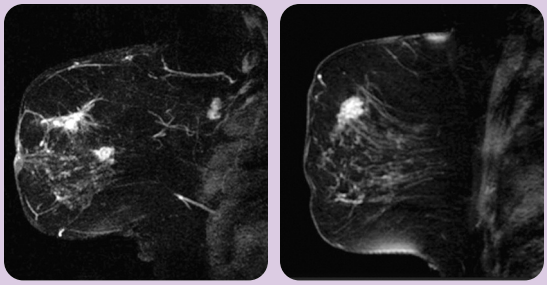


Figure 48. **Multicentric breast lesions.**

Foci vs. Mass

The size of the abnormality plays a role in likelihood of malignancy, as well. A **focus** or foci of enhancement is a dot-like area of enhancement <5 mm in size. A mass is a space-occupying lesion >5 mm. A mass generally has a 3D correlate on the pre-contrast or T2-weighted images.

An abnormality ≤ 5 mm has a likelihood of disease of approx 3%, whereas a mass ≥10 mm has a 25% to 31% likelihood of malignancy.[4]

Kinetic Curve

The wash-in and wash-out contrast enhancement pattern in breast tissues gives us the ability to create a kinetic curve for the tissue of interest (Figure 49).

There are three types of contrast enhancement patterns:[5]

- Type I curve has a rapid initial rise with the introduction of contrast and then has a rapid wash-out of contrast in the lesion. The likelihood of malignancy with this type of kinetic curve is approximately 87%.

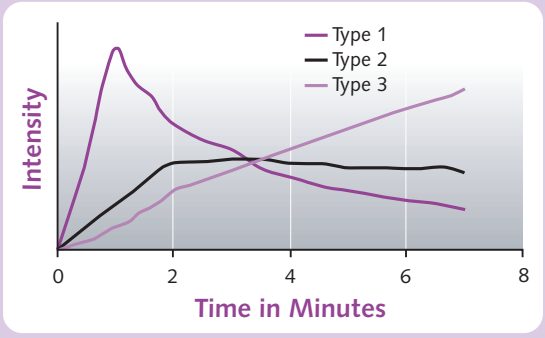


Figure 49. **Time intensity enhancement curves.**

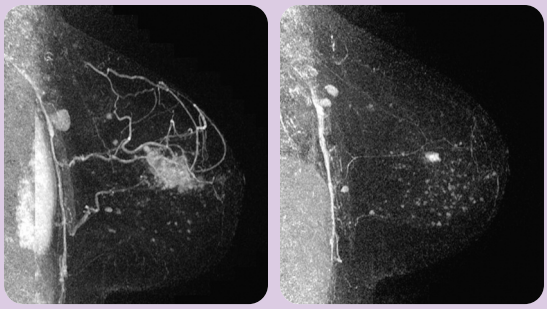


Figure 50. **Neoangiogenesis.**

- Type II curve also shows an initial rise with the introduction of contrast and then a plateau of contrast enhancement over time. This lesion has an indeterminate enhancement kinetic pattern. The likelihood of malignancy with this type of kinetic curve is approximately 64%.
- Type III curve has an initial rise with the introduction of contrast and a continuous enhancement of contrast in the lesion over time. This is a benign type of enhancement kinetic curve. The likelihood of malignancy with this type of kinetic curve is approximately 6%.

The growth of malignant lesions is dependent on **neoangiogenesis** – the formation of a new blood supply to feed tumor growth (Figure 50). Blood vessels in a malignant lesion are abnormal and leaky. This leakage causes contrast to wash out of tumors quickly. This rapid contrast wash-out is seen in the type III kinetic curve.

Malignant Tumors

Fortunately, the mortality rate for breast cancer in American woman has decreased in recent years because of earlier detection and advances in treatment and breast imaging.

Invasive Ductal Carcinoma

Invasive ductal carcinoma is the most frequently encountered cancer seen on breast MRI. It develops in the ducts and infiltrates the membranes of the ducts into the surrounding tissues. The MR sensitivity is 95-98% for invasive ductal carcinomas (Figure 51).[6]

Medullary & Mucinous Cancers

Medullary and **mucinous** cancers are rare, sub-types of ductal carcinoma. They appear similar to fibroadenomas on breast MRI, with distinct borders, and require careful pathological determination (Figure 52).

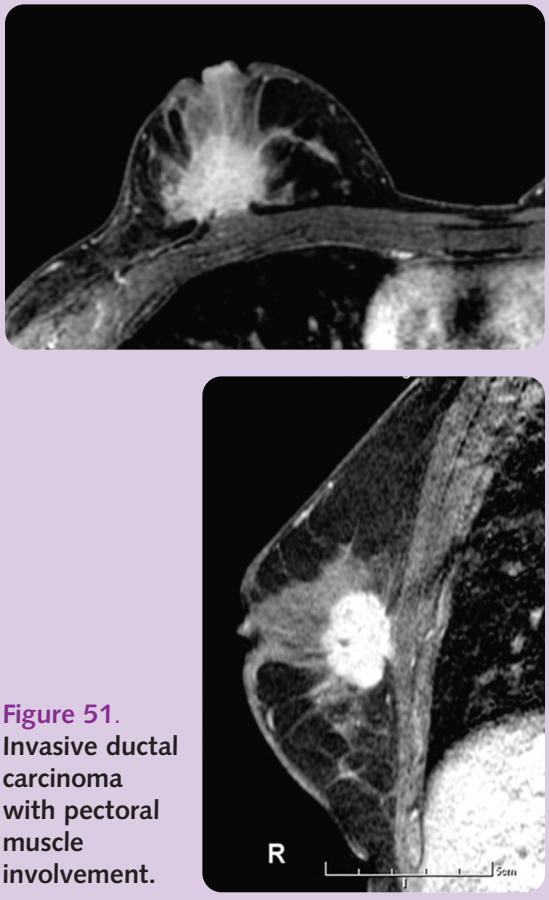


Figure 51. **Invasive ductal carcinoma with pectoral muscle involvement.**

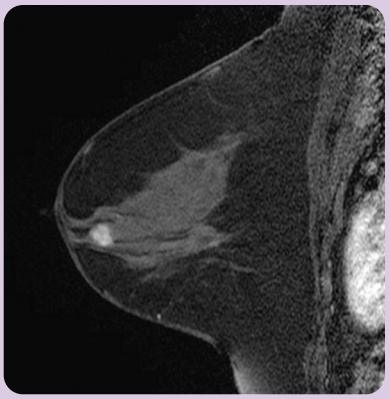


Figure 52. **Mucinous carcinoma.**

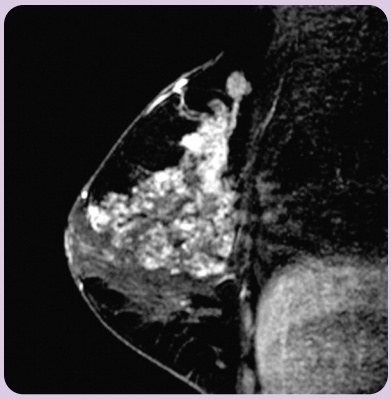


Figure 53. **DCIS segmental clumped enhancement.**

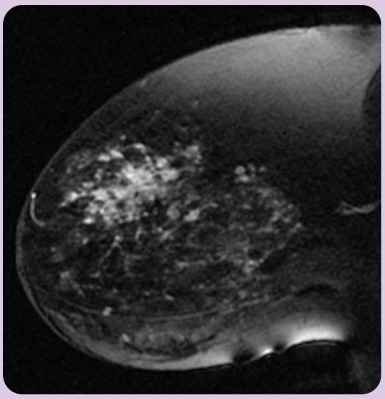


Figure 54. **Invasive lobular carcinoma.**

Ductal Carcinoma in-situ (DCIS)

Ductal carcinoma in-situ (**DCIS**) stays within the lining of the ducts with no invasion into the breast tissue. DCIS is considered precancerous. While not all DCIS will develop into cancer, it is generally treated surgically and with radiation therapy (Figure 53).

Lobular Cancers

Lobular cancers begin in the cells of the lobular units. Lobular cancer invades nearby tissue, spreading in a weblike pattern and making it difficult to diagnose. It is difficult to detect with all modalities but best visualized with breast MRI (Figure 54).

Inflammatory Cancer

Inflammatory cancer is an aggressive breast cancer that usually presents with redness, swelling, and pain. It often involves over half of the breast and commonly infiltrates the skin and mammary tissues. Inflammation occurs due to tumor invading the lymphatic system and blocking drainage. The skin can have an orange peel (**peau d'orange**) appearance. On MRI, the skin is thickened with heterogeneous enhancement, subcutaneous edema, and edema through the breast (Figure 55).

IMAGING THE AUGMENTED AND RECONSTRUCTED BREAST

The most common types of augmentation and reconstruction are implants, transrectus abdominis myocutaneous flap (TRAM), deep inferior epigastric perforator (DIEP), and silicone injections.

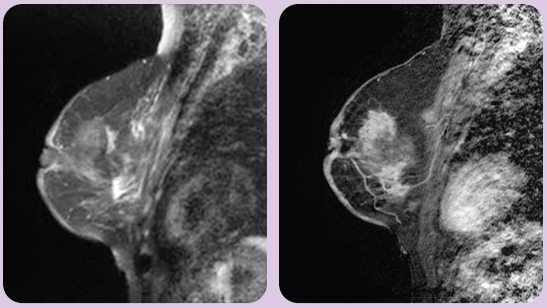
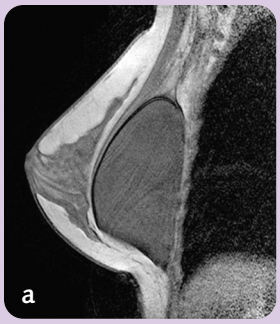


Figure 55. **Inflammatory cancer. Note enhancing skin thickening.**



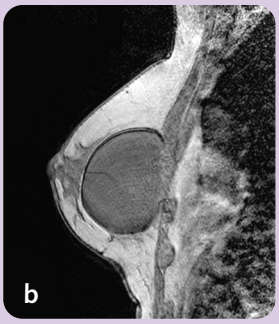
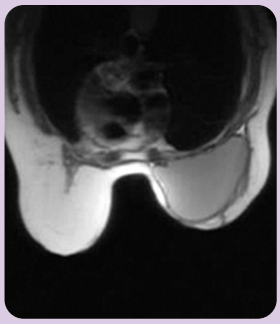


Figure 56. Implants.
(a) Subpectoral. (b) Subglandular.



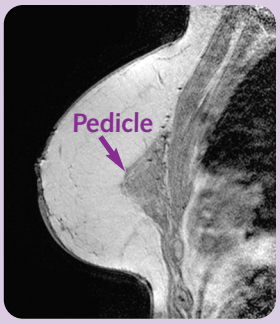


Figure 57.
TRAM flap with implant.

Implants

In post-mastectomy patients, silicone or saline implants can be used for reconstruction. The determination of using silicone or saline is made by the patient and her surgeon. Implants can be placed subpectorally or subglandularly, most often in the subpectoral location (Figure 56).

Prior to the insertion of the implant, a tissue expander is sometimes used to "stretch" the tissue to accommodate the future implant. Caution should be taken when interviewing patients undergoing reconstruction as there are several tissue expanders that are not MR compatible. After the tissue is stretched adequately, the expander is replaced with a permanent implant.

Transrectus Abdominis Myocutaneous Flap (TRAM)

Transrectus abdominis myocutaneous flap reconstruction uses the rectus abdominis muscle to supply blood to the fat and tissue used to form a new breast. There is also often associated fat necrosis. On MRI, there is an area of triangular tissue known as the **pedicle** that often shows susceptibility artifacts due to the surgical procedure. The pedicle is formed from part of the rectus muscle that has been moved from the abdominal wall (Figure 57).

Deep Inferior Epigastric Perforator (DIEP)

The **deep inferior epigastric perforator** procedure takes tissue and fat from the lower abdomen but keeps the muscle intact.

Silicone Injections

Silicone injections are a type of augmentation rarely used today. It is important to image with a water-suppressed inversion recovery to visualize residual silicone vs granulation tissue.

MRI-GUIDED BREAST BIOPSY (MRBX)

If an area of abnormality is seen on breast MRI and cannot be reproduced by either mammography or ultrasound, an MRI-guided breast biopsy may be performed. All centers providing BMRI should have the capability to provide MRI-guided breast biopsy.

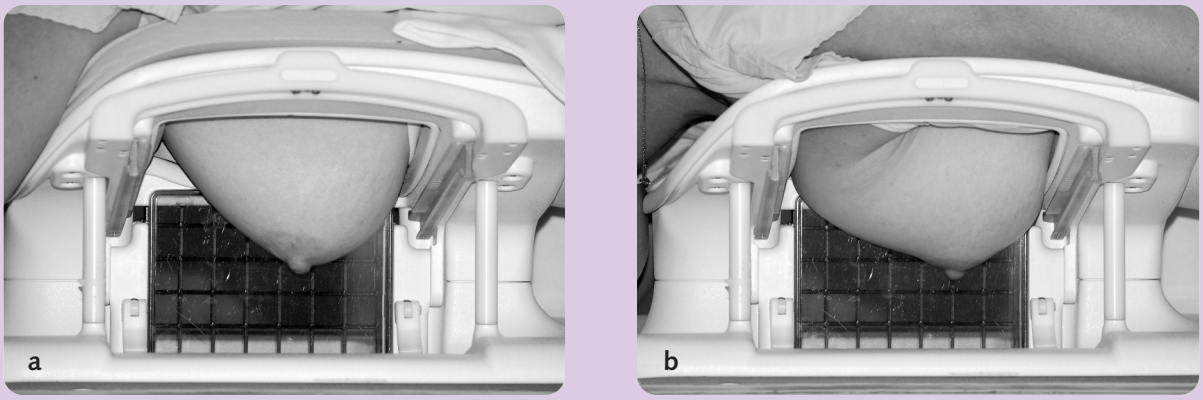


Figure 58. (a) Patient positioning, arm up and with the coil pad. (b) Removing the coil pad and placing the patient's arm down at her side allows for better posterior access.

Patient Care and Comfort

Patients arriving for an MRBX may require additional attention. It is important for the patient to feel as comfortable as possible to alleviate stress and to help eliminate motion during the procedure. A dedicated breast MRI technologist can make the procedure much easier for the patient, both physically and emotionally.

As with any breast biopsy, check to be sure that the patient has discontinued aspirin, ibuprofen, vitamin E, or any other blood-thinning medications prior to the procedure.

It is important to keep this procedure as simple as possible. The diagnostic breast MRI should be reviewed and the biopsy approach determined by the radiologist prior to the procedure to minimize the time the patient is in compression. The team should thoroughly review the case, understand what needs to be biopsied, and determine the approach and patient position before beginning. A set of images showing the location of the lesion to be targeted should be at the MR console for reference.

After the patient arrives and the approach determined, it is important to make the patient as comfortable as possible. A head support, blanket, and the presence of a technologist or nurse at all times can put the patient at ease.

Patient Positioning

Patient positioning is critical for an accurate biopsy. Determining the optimal approach prior to the procedure saves time, and with proper positioning the procedure will be more comfortable for the patient. The diagnostic BMRI study, as well as prior mammography and sonograms, should be reviewed and an appropriate approach determined prior to the arrival of the patient. Is the lesion on the lateral or medial side of the breast? Is the lesion in the anterior or posterior portion of the breast? Will the patient need to be elevated in the coil to access a very anterior or retro-areolar lesion, or is the lesion so posterior that the patient will need to be lowered down into the coil? Pulling the breast, using a smaller pad on the coil, and placing the patient's arm down by her side allows for better posterior access (Figure 58). Is there anything to limit access to the lesion – post-surgical seroma or a large blood vessel? It is important to know these answers before you begin.

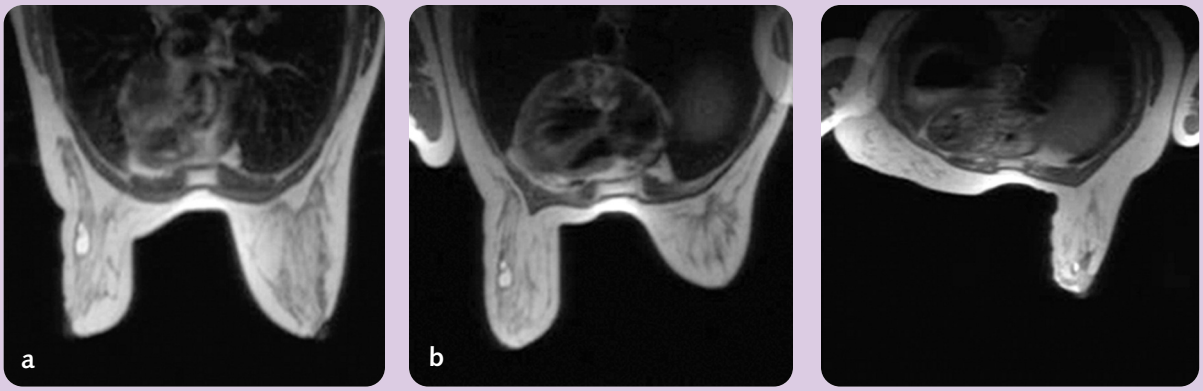


Figure 59. Posterior lesion. (a) Poorly positioned breast. (b) Pull the breast for better access.

Figure 60. Medial approach with wedge on lateral side.

Breast Placement

It is important to pull the breast into the coil to provide both better access and compression. Care should be taken not to pinch the patient or place the compression plate too tightly when immobilizing the breast (Figure 59).

If compression is uneven, a wedge can be placed to help provide more uniform compression (Figure 60).

Once the patient is comfortable and properly positioned and the breast is in compression, a vitamin E capsule or contrast-filled **fiducial** is placed near the expected region of the abnormality.

Scan Protocol

A simple protocol is all that is needed for an MRI-guided biopsy (Table 4, page 48). A three-plane localizer is used to determine that the patient is adequately positioned and 3D sagittal T1- weighted fat-suppressed sequence is used to visualize the breast and lesion. Only the area of the questionable abnormality needs to be scanned. Be sure to include the face of the compression grid in this scan. A pre-contrast scan is done to ensure the area of interest is accessible and the fiducial can be seen.

Contrast Administration

Contrast is administered only after it is determined that the area of interest can be visualized and is accessible within the compression grid. Contrast is given manually and post-contrast images are acquired immediately following contrast injection. It is not necessary to use a power injector for this procedure; however, it is important to work quickly and efficiently to reduce lesion washout and to minimize background enhancement.

Once the area of interest is identified on post-contrast images, the coordinates of the lesion are determined within the compression grid and the depth of the lesion is calculated.

If the area of interest is not visualized post-contrast, perform two to three additional post-contrast scans and reassess. Was the contrast adequately administered? Is the compression too tight, not allowing adequate blood flow to the breast? Is the lesion truly a suspicious lesion on the diagnostic study or

fibrocystic change that might not be seen at this point in the patient's menstrual cycle?

Biopsy Needle Placement

The location of the biopsy needle placement can be determined once the area of interest is identified on the post-contrast images.

For mass-like lesions, it is important to choose a location that will not "skewer" the lesion, as this is likely to push away or obliterate the lesion. Instead, the biopsy needle should be placed immediately adjacent to the targeted lesion.

If the area of interest is linear or is an area of large clumped enhancement it may be best to target the center of the area.

Prepping the Skin

While the location of the needle placement is being determined, the patient should be brought out of the magnet. It is important that a technologist or nurse be with the patient to avoid patient movement, ensuring the lesion will be in the calculated location. At this point, the biopsy device can readied. The patient's breast is cleaned with a Chloraprep® or Betadine® and anesthetized with lidocaine at the surface and to the depth of the lesion.

Introducer Placement

An introducer guide needle with an introducer sheath is placed to the appropriate depth of the area of interest. The guide needle is removed and replaced with a plastic **obturator**. The patient is scanned to assess the placement of the introducer. Did the lesion move with the insertion of the guide needle? Is the introducer properly placed? If yes, then the biopsy device can be placed and samples taken. If the lesion has moved with the insertion of the guide needle, recalculate the lesion depth based on the post-introducer images and make the appropriate adjustments. Replace the obturator and rescan the patient.

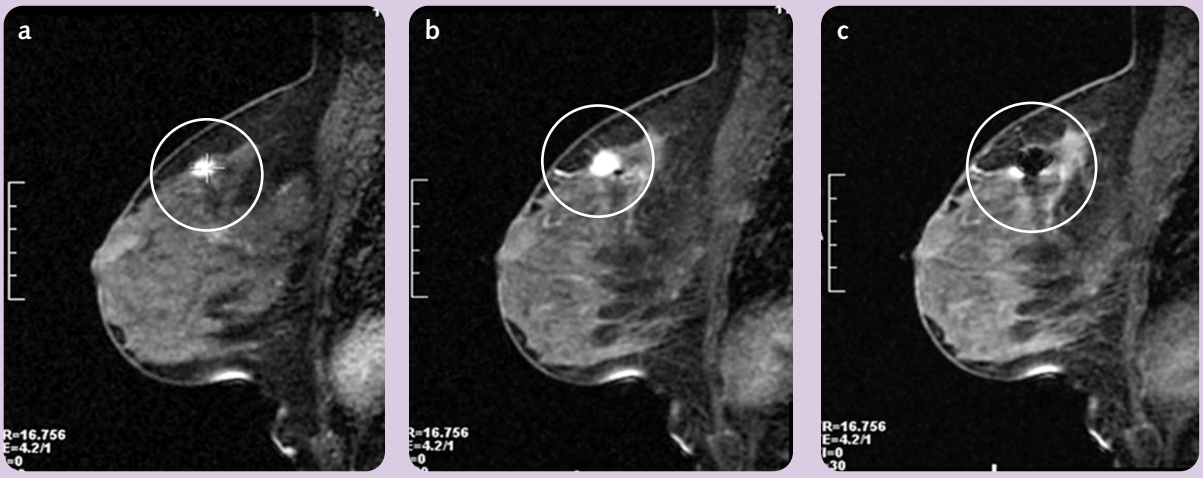


Figure 61. (a) Post-contrast. (b) Post-obturator. (c) Post-biopsy.

Tissue Sampling

It is only necessary to biopsy in the direction of the lesion. Using a consistent method to determine the direction of tissue sampling reduces the chance for error. The direction of tissue sampling is determined in relation to the guide needle: is the area of interest toward the patient's head, chest, feet, or nipple? Remember the position of the patient on the table will be different from the patient's position on the console monitor. Take great care in determining the correct direction to biopsy.

Was the lesion adequately sampled? Care should be taken to compare the post-biopsy images with the post-introducer images, as the lesion may have moved after the initial post-contrast images. It is important to adequately sample the lesion (Figure 61). If a hematoma appears, one or two biopsy cores will help eliminate it so that the biopsy cavity can be better seen. If the lesion washes out, use anatomical landmarks to help determine your position. Once it has been determined that the lesion was adequately sampled, an MR-compatible biopsy marker is deployed. It is not necessary to scan after the marker is deployed.

Pathological correlation must be done when the biopsy results become available. If the results are discordant with the anticipated outcome, the patient may need surgical excision.

BIOPSY PROCEDURE OVERVIEW

1. **Position patient, pull/immobilize breast, place breast in compression, use wedge if needed.**
2. **Initial scanning – 3 plane localizer and 3D T1 fat-suppressed sagittal of breast.**
3. **Check location of breast in compression grid using diagnostic MRI and physical landmarks.**
4. **Inject contrast agent.**
5. **Scan immediately.**
6. **When lesion is visualized, the technologist will prepare biopsy device.**
7. **Determine the physical location of lesion using grid coordinates.**
8. **Prepare breast with topical cleaning and local numbing agent.**
9. **Introduce guide needle.**
10. **Re-scan patient to determine that the needle is correctly placed.**
    a. **If correct, proceed with biopsy.**
    b. **If not correct, reposition guide needle and rescan.**
11. **Scan to determine if the lesion in question has been adequately biopsied.**
    a. **If yes, always deploy a biopsy marker.**
    b. **If no, take more biopsy cores as needed.**
12. **Hold manual compression; apply Steri-Strips™, ice pack, and compression.**
13. **Obtain post-biopsy mammogram.**
14. **Pathology correlation must be done.**

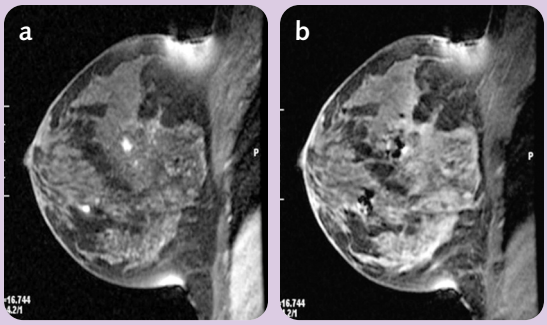


Figure 62. **Multiple biopsy. (a) Post-contrast. (b) Post-biopsy.**

Patient Care after Biopsy

After completion of the biopsy, the patient can be removed from compression. Pressure is held at the biopsy site until bleeding has stopped, and Steri-Strips™ should be applied, along with an ice pack and compression binder. A post-biopsy mammogram is performed to record placement of the biopsy marker. Post-biopsy care instructions must be given to the patient at discharge.

Multiple Biopsies

If more than one biopsy or bilateral biopsy is needed, more than one area can be targeted during the biopsy procedure (Figure 62). Care must be taken to label samples correctly, remembering to be consistent in the approach taken to label tissue samples.

Table 2.

SAMPLE BREAST MR IMAGING PROTOCOL

	Localizer	Calibration	Right/Left Sagittal T2 F/S	Sagittal Parallel Imaging Non-F/S	Sagittal Parallel Imaging Pre/post	Axial Parallel Imaging Post F/S
Plane	3-Plane	Axial	Sagittal	Sagittal	Sagittal	Axial
FSP	SSFSE	Fast GRE	FSE-XL	Parallel imaging	Parallel imaging	Parallel imaging
TR	MIN		~5000	SET	SET	SET
TE/TI	MIN		85	IN-PHASE	IN-PHASE	IN-PHASE
ETL/FLIP			14	10	10	10
RBW	83		21	32	42	42
FOV	38	48	~20	~20	~20	~32
SLICE TK/SKIP	7	8	4/1	3mm	3mm	3mm
MATRIX	256x192		256x192	320x256	384x224	384x350
NEX	1		2	1	1	1
SLICES	15/12/3	46	~26	100	500	100
OPTIONS			FAT/SAT, PURE, NPW	NPW, ASSET, PURE	NPW, ASSET, FAT/SAT	PURE, FAT/SAT

Right and left sagittal T2 FSE are done separately. Sagittal fat/sat parallel imaging pre/post-contrast done with multi-phase imaging. 5 phases total – 1 pre/4 post-contrast. Keep scan times on dynamic sagittal parallel imaging pre/post-contrast scans ≤ 2 minutes. To increase scanning area, increase slice thickness, not number of slices.

Table 3.

SAMPLE SILICONE IMPLANT MRI PROTOCOL

	Localizer	Calibration	Right/Left STIR	Right/Left STIR Water Sup.	Axial STIR Water Sup.	Axial STIR	Sag. Parallel Imaging Non F/S
Plane	3-plane	Axial	Sagittal	Sagittal	Axial	Axial	Sagittal
PSD	SSFSE	FAST GRE	FSE-IR	FSE-IR	FSE-IR	FSE-IR	Parallel imaging
TR	MIN		~8000	~8000	~7500	~7500	SET
TE/TI	MIN		50/150	50/150	50/150	50/150	IN-PHASE
ETL/FLIP			12	12	12	12	
RBW	83		32	32	32	32	32
FOV	38	48	~20	~20	~32	~32	~20
SLICE THK/SKIP	7	8	4/1	4/1	4/1	4/1	3mm
MATRIX	256x192		320x160	256x192	256x192	320x224	320x256
NEX	1		2	1	1	1	1
SLICES	15/12/3	46	~26	~26	~30	~30	100
OPTIONS			NPW, FC, PURE	NPW, FC, PURE WATER-SAT	NPW, FC, PURE WATER-SAT	NPW, FC, PURE	NPW, ASSET, TURBO+2

This protocol is done only if looking for a silicone implant rupture. If scanning for a breast mass with a questionable implant rupture, add sagittal parallel imaging fat-sat pre/post-sequence and axial parallel imaging post-contrast sequence to this protocol. Left and right STIR series should be done separately.

Table 4.

SAMPLE BREAST MRI-GUIDED BIOPSY PROTOCOL

	Localizer	Sagittal 3D Fat/Sat	Opt. Axial SPGR	Opt. Sagittal Non-Fat/Sat
Plane	3-plane	Sagittal	Axial	Sagittal
PSD	SSFSE 3-Plane	FSPGR	FSPGR	FSPGR
TR	MIN	---	---	---
TE/TI	MIN	IN-PHASE	IN-PHASE	IN-PHASE
ETL/FLIP		30	30	30
RBW	83	32	32	32
FOV	38	20	20	20
SLICE THK/SKIP	5mm	3mm	3mm	3mm
MATRIX	256x192	192x160	192x160	192x160
NEX		1	1	1
OPTIONS		NPW, FAT/SAT	NPW, FAT/SAT	NPW
# SLICE	12/12/3	~18	~18	~18

POINTS FOR PRACTICE

1. **What is the difference between specificity and sensitivity of breast MRI?**

   Breast MRI has a high sensitivity - it is very good at picking up invasive breast cancers. Because of the high sensitivity, it also picks up everything else, as well. The specificity is lower because other enhancing tissues in the breast can give a false positive for breast cancer.

2. **What groups should receive high-risk screening with BMRI?**

   The American Cancer Society Guidelines recommends BMRI for women:
   - with the BRCA mutation
   - who have a first-degree relative with breast cancer diagnosed under the age of 40
   - a lifetime risk of breast CA of ≥ 20%
   - a history of chest radiation between ages 10 - 30
   - other genetic syndromes

3. **Describe the typical breast MRI scan protocol.**

   The basic breast cancer protocol should include a 3-plane localizer. This series should be done with relatively thin slices and non-fat-suppressed with T2 weighting. This series is required to prescribe future series and to check for any incidental findings outside of the breast, including liver, lung, and bone lesions, and the chest wall. Appropriate positioning of the patient in the coil also can be verified on the localizer.

4. **In what plane should BMRI be performed?**

   Breast MR imaging can be done in the sagittal plane to keep the field of view small, from 20 - 24 cm, and the resolution at its greatest, although some centers prefer to scan in the axial plane.

5. **What is background enhancement? Is it clinically significant?**

   Background enhancement is the normal enhancement within the breast parenchyma. It varies by patient and is associated with hormonal changes, including those related to the menstrual cycle, hormone replacement therapy, and hormonal chemotherapy. Background enhancement is also affected by fibrocystic changes and individual differences. It is not directly related to breast density. Background enhancement can be classified as minimal, moderate, and marked and is a benign finding.

6. **What is fibrocystic change, and why can it be difficult to differentiate between this and malignancy? When is the preferred time during the menstrual cycle for women to be scanned?**

   Fibrocystic change refers to the change in cell characteristics of the glandular tissue due to normal hormonal fluctuations during the menstrual cycle. Breast tenderness, pain, and lumpiness can be associated with fibrocystic change. Although it is a benign finding, it can be difficult to differentiate between this change and malignant findings because symptoms can be indicative of both. Dramatic changes can be seen when scanning women during different times of their menstrual cycle. The time in the patient's cycle should be noted to assist the radiologist in differentiating between normal fibrocystic change and malignancy. Imaging during Day 7-14 of the cycle is the preferred time frame in premenopausal women.

POINTS FOR PRACTICE

7. What is a kinetic curve, and what can it tell us about lesion enhancement?

The wash-in and wash-out contrast enhancement pattern in the breast tissues provides the ability to create a kinetic curve for the particular tissue of interest. Type I curve has a rapid initial rise with the introduction of contrast and then has a rapid wash-out of contrast in the lesion. The likelihood of malignancy with this type of kinetic curve is approximately 87%. Type II curve also shows an initial rise with the introduction of contrast and then a plateau of contrast enhancement over time. This lesion has an indeterminate enhancement kinetic pattern. The likelihood of malignancy with this type of kinetic curve is approximately 64%. Type III curve has an initial rise with the introduction of contrast and a continuous enhancement of contrast in the lesion over time. This is a benign type of enhancement kinetic curve. The likelihood of malignancy with this type of kinetic curve is approximately 6%.

8. When is an MRI-guided biopsy indicated, and what type of scan protocol should be used?

When an area of abnormality is seen on BMRI and cannot be reproduced by either mammography or ultrasound, and BMRX may be performed.

A simple protocol is all that is needed for an MRI-guided biopsy. A three-plane localizer is used to determine that the patient is adequately positioned and 3D sagittal T1-weighted fat suppressed sequence is used to visualize the breast and lesion. Only the area of the questionable abnormality needs to be scanned. Be sure to include the face of the compression grid in this scan. A pre-contrast scan is done to ensure the area of interest is accessible and the fiducial can be seen.

REFERENCES

1. National Cancer Institute 2008 Surveillance, Epidemiology and End Results. Available at: http://seer.cancer.gov/statfacts/html/breast.html Accessed July 1, 2009.
2. American Cancer Society Guidelines for high-risk screening. Available at: http://www.cancer.org/docroot/NWS/content/NWS_1_1x_MRI_Finds_Breast_Cancer_in_High-Risk_Women.asp Accessed July 1, 2009.
3. Lehman CD, Gatsonis C, Kuhl CK, et al. MRI evaluation of the contralateral breast in women with recently diagnosed breast cancer. *N Engl J Med.* 2007 Mar 29;356(13):1295-1303. Epub 2007 Mar 28.
4. Liberman L, Mason G, Morris EA, Dershaw DD. Does size matter? Positive predictive value of MRI-detected breast lesions as a function of lesion size. *AJR Am J Roentgenol.* 2006 Feb;186(2):426-430.
5. Kuhl CK, Mielcareck P, Klaschik S, Leutner C, Wardelmann E, Gieseke J, Schild HH. Dynamic breast MR imaging: are signal intensity time course data useful for differential diagnosis of enhancing lesions? *Radiology.* 1999 Apr;211(1):101-110.
6. Berg WA, Gutierrez L, NessAiver MS, Carter WB, Bhargavan M, Lewis RS, Ioffe OB. Diagnostic accuracy of mammography, clinical examination, US, and MR imaging in preoperative assessment of breast cancer. *Radiology.* 2004 Dec;233(3):830-849. Epub 2004 Oct 14.

All images, tables and protocols courtesy of Fairfax Radiological Associates, Fairfax, VA, unless otherwise noted.