The Application of Breast MRI in Staging and Screening for Breast Cancer

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Contrast-enhanced breast magnetic resonance imaging (MRI) is a relatively new but increasingly used modality for the detection of breast cancer. MRI has demonstrated utility in identifying additional tumor foci and extent of disease in patients with known breast cancer. This is especially useful with invasive lobular carcinoma, which is difficult to evaluate on mammography. MRI has been found to identify the primary tumor in 70% to 86% of cases of occult breast cancer. Contrast-enhanced breast MRI has shown some usefulness in the detection of residual cancer following surgery but is limited by postoperative changes. In patients who have undergone neoadjuvant chemotherapy, breast MRI is most accurate in those patients in whom there is little or no response to chemotherapy. The use of contrast-enhanced breast MRI for breast cancer screening is controversial. It has only been used in a few small studies of high-risk patients. The limitations of breast MRI include uptake in benign lesions and normal tissue, sensitivity for ductal carcinoma in situ, cost, and availability. This paper will discuss the uses, benefits, and limitations of contrast-enhanced breast MRI in the staging and screening of breast cancer.

Contrast-enhanced breast magnetic resonance imaging (MRI) is a relatively new modality for the detection of breast cancer, but its use has been increasing exponentially with the development of new techniques and applications. This paper will discuss the uses, benefits, and limitations of contrast-enhanced breast MRI in the staging and screening of breast cancer.

Gadolinium-diethylenetriamine penta-acetic acid (DTPA) contrast-enhanced MRI to evaluate breast cancer was first described independently by two groups in 1989.[1,2] Since those first studies, a large amount of data has been accumulated, but there is no consensus as to technique, interpretation criteria, and indications for use (as there is for mammography and sonography). Breast MRI does offer a highly sensitive imaging modality for breast cancer without radiation, but MRI is not a replacement for mammography or breast ultrasound. It is, like ultrasound, another problem-solving tool for the detection of breast cancer.

Breast MRI involves evaluation of the breast or breasts prior to and after the administration of gadolinium- DTPA intravenous contrast. Images of the breast(s) are obtained immediately after the administration of the contrast bolus and repeated three to five times over several minutes. This results in multiple images of each slice of breast tissue, demonstrating the change in contrast enhancement over time. The presence, morphology, and pattern of contrast enhancement are evaluated for suspicious lesion(s).

Contrast-enhanced breast MRI is based on the production of angiogenic substances by tumors that result in the development of new vessels to supply the tumor. These new vessels are abnormal. They are permeable, have arterial-to-venous shunting, and are not associated with the concomitant production of lymphatics.[3] This neovascularity results in rapid enhancement of the tumor relative to the normal issue. The sensitivity of contrast-enhanced MRI in detecting breast cancer is high, ranging from 88% to 100%,[1,2,4] but the specificity ranges from 37% to 96%.[1,2,4-6] This variable specificity is a limitation in the use of breast MRI.

Imaging of breast implants for rupture or free silicone was the first widely accepted indication for breast MRI. Evaluation of breast cancer patients for tumor extent, occult disease, and posttreatment planning are becoming common applications. Additional uses of breast MRI to further assist in the assessment of questionable mammographic or physical examination findings is emerging.

Contrast-enhanced MRI for breast cancer screening is controversial.

Breast Cancer Staging With Contrast-Enhanced MRI

FIGURE 1
Multifocal or multicentric disease has been demonstrated in 31% of patients with known breast cancer.[7] Residual breast cancer at the lumpectomy site can result in recurrence. Therefore, successful treatment depends on accurate presurgical knowledge of the extent of the disease. Mammography and sonography can often locate the primary tumor, but small, multifocal, or multicentric lesions may be missed unless they are actively sought out.

In a study comparing imaging modalities for assessing breast cancer, mammography found 90% of the index tumors, ultrasound found 85%, and MRI found 98%. Tumor size was underestimated by 14% on mammography and by 18% on ultrasound, but the size of the tumor at histology was not significantly different from that seen on MRI.[8] In patients with a known primary tumor, breast MRI can better establish the extent of the disease (Figure 1). Contrast-enhanced breast MRI identified additional malignant foci in the ipsilateral breast in 22% to 34% of patients with known breast cancer.[6,7] Mammographically occult synchronous tumors in the contralateral breast were found in 5% of patients.[9]

**Invasive Lobular Carcinoma**

MRI is especially useful in evaluating invasive lobular carcinoma, as it is difficult to identify on mammography. It has been reported that 19% of patients with invasive lobular carcinoma have no mammographic findings.[10] This may be due to the growth pattern of invasive lobular carcinoma, which has been classically described as groups of malignant cells in a one- to two-cell-thick linear arrangement. This neoplasm does not form a sheet of tumor cells, so there is no tumor mass. Often, what is seen on mammography is the body's desmoplastic response to the tumor. The most common mammographic appearance is an asymmetry or ill-defined mass that is the same density as the surrounding breast tissue and is hard to differentiate from the normal parenchyma.[10] Sonography can identify almost 90% of cases of invasive lobular carcinoma,[11] but often, ultrasound is only done when a mammographic or clinical abnormality is present in the area. Invasive lobular carcinoma is more likely to be multicentric and bilateral than ductal carcinoma. These factors combine to make diagnosis and treatment of invasive lobular carcinoma difficult.

MRI is useful in evaluating patients with invasive lobular carcinoma. MRI has identified additional tumor foci in 22% to 40% of patients with known invasive lobular carcinoma[12,13] and contralateral foci in 9% of patients.[12] Although MRI has been seen to be sensitive for lobular carcinoma, reports have indicated false-negative MRI findings. A few cases have been reported in which there is little or no contrast enhancement.[8,14] The enhancement pattern seen in invasive lobular carcinoma may also make detection difficult. A discrete mass was found with contrast-enhanced breast MRI in 30% to 56% of invasive lobular carcinoma cases, and 39% to 61% demonstrated multifocal or regional enhancement.[13,15] This regional enhancement can be confused with fibrocystic or glandular uptake and may be underidentified. The extent of disease on pathology has been seen to correlate with the MRI findings in 85% of patients.[14] Due to MRI findings, 50% of patients with invasive lobular carcinoma undergoing preoperative breast MRI had a change in their surgical management.[16] MRI can be a useful addition to the evaluation of invasive lobular carcinoma and should be considered for preoperative evaluation of the disease (Figure 2).
Need for Cautious Interpretation

The identification of more extensive disease can determine if the patient is a candidate for mastectomy or breast-conservation therapy. Of the patients with additional foci, 13% to 21% had their treatment changed to mastectomy or to lumpectomy with wider local excision because of MRI findings.[7,16] Breast MRI can also determine chest wall invasion better than mammography or ultrasound. Tumor involvement of the chest wall, regardless of primary tumor size, changes the disease stage to IIIIB.

However, prudence should be used with the application of breast MRI in evaluating breast cancer patients. There is overlap of contrast enhancement in benign and malignant breast processes on MRI, and 4% to 21% of the patients undergoing preoperative breast MRI have false-positive findings necessitating additional biopsy and worry.[7,9,16,17] The patient needs to realize that there is a possibility of false-positive and falsenegative findings with MRI. Physicians should help patients understand what this may mean in regard to their treatment plan.

The high sensitivity of contrast-enhanced breast MRI has created the impression that it is the gold standard for evaluation of breast cancer. The assumption is made that any enhancing area on MRI is a carcinoma. It is important to recognize that 29% to 80% of lesions with suspicious enhancement on MRI are benign on histology.[7,9,16,17] Some patients have become so concerned by the presence of an abnormality on breast MRI that they go directly to prophylactic mastectomy, at which point no malignancy may be found in the specimen.[9,17] Liberman et al found that 9% of patients with a suspicious MRI finding underwent prophylactic contralateral mastectomy, compared to 3% with no findings.[9]

Occult Breast Cancers

Axillary metastasis without clinical or mammographic evidence of the primary has been reported to occur in less than 1% of cases of breast cancer.[18] If the primary tumor cannot be found, the patient often undergoes modified radical mastectomy followed by chemotherapy.[18,19] Many surgeons are hesitant to perform a mastectomy without demonstrated breast malignancy. No evidence of carcinoma is found in one-third of these "blind" mastectomy specimens.[18]

Although the number of patients is small, studies of occult breast cancer have found that 70% to 86% of the primary tumors can be identified on contrast-enhanced breast MRI.[19,20] The majority of the cancers appeared as focal-enhancing lesions with spiculated or irregular borders. False-positive findings included patients with no tumor found at pathology or cancer found in areas of the breast that were not the same as the enhancing lesion.[20] Finding the primary tumor allowed 37% to 41% of these women to undergo breast-conservation therapy.[19,20] Tumor was found in 81% of the specimens in patients with MRI findings.[19] The lack of an enhancing lesion on MRI changed the treatment plan to axillary lymph node dissection and breast radiation therapy in a few of the study cases.[19]

Not all lesions seen on MRI are malignant, and biopsy is necessary before a final treatment course can be determined. Generally, once the lesion is found, the mammograms are reassessed and an ultrasound is performed. If the lesion is seen on ultrasound, then a faster and less expensive ultrasound-guided biopsy can be performed. Otherwise, MRI-directed biopsy can be performed at facilities with the appropriate equipment.

Follow-up Post-Neoadjuvant Chemotherapy

Neoadjuvant chemotherapy is given to patients after the diagnosis of malignancy has been made but prior to definitive surgical treatment, to decrease the size of the tumor. Recurrence rates and positive margins have been reported to be similar to those seen in patients with early-stage cancers.[21] Therefore, for a woman with advanced disease, neoadjuvant chemotherapy can enable the use of breast-conservation therapy as an alternative to mastectomy without a difference in survival.

The extent of response to chemotherapy and amount of residual tumor determines the treatment options in this setting. Delineating the response poses a clinical challenge. Traditionally, palpation, mammography, and sonography have been used, but edema and necrosis at the tumor site may hinder measurement of the tumor's true size. Clinical breast exam has been found to underestimate residual disease. In one study, the average tumor size after neoadjuvant chemotherapy was 2.2 cm on clinical breast exam and 3.0 cm on final pathology[22]; 63% of patients who were thought to have had a complete response to chemotherapy on clinical exam had residual tumor on final pathology.[23]
Mammography does not show much better results. Vinnicombe et al found that five of eight patients with complete response to chemotherapy on mammography had residual tumor at excision.[24] Mammographic assessment of response is more difficult in denser breasts, with ill-defined tumors, or in areas of architectural distortion alone.[25] Sonography may be more accurate with well-defined tumors but may still produce erroneous results. If conventional imaging evaluation is done during the course of chemotherapy, then this underestimation of response may cause continuation of ineffective therapy and delay in definitive treatment.

FIGURE 3

Biopsies in the 9, 11, and 3 O’clock Positions in the Right Breast of a 44-Year-Old Woman Demonstrated Poorly Differentiated Invasive Ductal Carcinoma and Ductal Carcinoma In Situ

MRI provides not only an anatomic evaluation of the tumor but also a physiologic one. Necrosis and edema do not influence the MRI findings. As the MRI findings are based on the vascularity of the tumor, the effect of chemotherapy agents that inhibit tumor angiogenesis can be seen (Figure 3). In one study, specificity for partial response to chemotherapy was 93%, with 82% accuracy.[26] In addition, studies have found that MRI is better at determining the lack of response to neoadjuvant chemotherapy than at determining the extent of response.[22,26] Rieber et al found that 56% of patients with a partial response to chemotherapy had an average MRI tumor measurement of 1.1 cm over the tumor size on final pathology. Among patients with complete response on MRI, 67% had residual tumor up to 5 cm in diameter at excision. This underestimation was more marked in invasive lobular carcinoma, with seven of nine patients showing larger tumors at final pathology than expected by MRI.[26] This discrepancy may cause difficulty for the surgeon when selecting between mastectomy and lumpectomy. The result may be positive surgical margins with increased recurrence.

The change in appearance on postchemotherapy MRI may be due to decreased tumor size, change in tumor cellularity, or change in tumor vascularity. Diminished contrast enhancement following chemotherapy would support a reduction in tumor vascularity. Decrease in peak contrast uptake and flattening of the contrast uptake curve have been seen in tumors following chemotherapy.[22,26] The shape of the contrast uptake curve is a factor in the evaluation of an enhancing lesion to determine if it is suspicious for malignancy. Due to the neovascularity, there is a greater vascular supply to the carcinoma, resulting in contrast reaching the tumor faster than the surrounding normal parenchyma. This rapid "wash in" is accompanied by a rapid "wash out" in highly suspicious lesions as the contrast moves out of the tumor through arterial venous shunting. Therefore, a tumor would be expected to have an early, steep rise to peak enhancement with a decrease in enhancement almost as quickly. The change in the contrast uptake curve may account for the underestimation of response to chemotherapy and may mask satellite lesions. If neoadjuvant chemotherapy is being considered, a prechemotherapy MRI would permit identification of the extent of the disease and allow for more accurate posttreatment evaluation.

MRI prior to initiating neoadjuvant chemotherapy is especially important if the disease is multicentric or diffuse. These lesions are not very conspicuous and become even less so with decreased contrast enhancement resulting from neoadjuvant chemotherapy. MRI can also suggest that the carcinoma is more extensive than what is found at final pathology. Rosen et al found that contrast-enhanced MRI overestimated tumor size by 1 cm or more in 33% of their patients. Most of these were nonfocal lesions.[22] Enhancement in diffuse disease may mimic benign breast enhancement, causing it to appear larger. MRI evaluation during the chemotherapy course may readily demonstrate a lack of response and allow earlier changes to the treatment regimen. Rieber et al found that more reliable results were obtained with contrast-enhanced breast MRI imaging performed at least 6 weeks after the initiation of chemotherapy.[26]

Characterizing Ambiguous Mammographic Findings

Contrast-enhanced breast MRI is not a replacement for mammography, but it can be used, like sonography, as an adjunct to help clarify ambiguous findings. Sonography should be performed first
to evaluate any questionable mammographic findings, as it is readily available, faster, and less expensive than MRI. Lesions that are mammographically or sonographically suspicious should be biopsied regardless of the MRI results. MRI can aid in the management of findings that are not obviously worrisome but are not definitively benign. Lee et al looked at equivocal mammographic findings and identified a corresponding suspicious enhancing lesion on MRI for 30% of these. Of the lesions seen on MRI, 35% were malignant at biopsy. In cases in which ultrasound was also performed, 81% of the ultrasound results correlated with the MRI and histologic findings.[27]

MRI is more helpful in cases of postsurgical scarring or in lesions that are thought to most likely be benign on mammography or sonography. Often, due to either patient anxiety or personal/family history of breast cancer, the radiologist may worry about the risk of not proceeding to biopsy with an ambiguous lesion. A negative MRI result allows greater confidence in forgoing biopsy for short-interval follow-up with these patients (Figures 4 and 5).[27,28]

Another entity that is difficult to diagnose on mammography, sonography, and clinical exam is diabetic mastopathy. In women with this disease, dense fibrous areas are seen and can be palpated. On mammography and sonography, these findings can be indistinguishable from malignancy, and biopsy is often recommended. Diabetic mastopathy is often bilateral and may occur multiple times over the course of a woman's life. MRI may help alleviate the need for biopsy in these patients, as diabetic mastopathy generally does not demonstrate a suspicious contrast uptake pattern.[29]

**Postsurgical Evaluation**

Contrast-enhanced breast MRI has been used to evaluate breast cancer patients whose excisional biopsy specimens were found to have positive or close margins. The postsurgical edema, seromas, and scarring make mammography less reliable. On sonography, distortion of the tissue planes results in mass-like shadowing. Contrast-enhanced breast MRI of the postoperative breast is not affected as much by these problems and can help determine the extent of additional surgery. Studies from the University of Pennsylvania found that 60% to 85% of these patients had residual disease on their final pathology, and 57% to 61% of the patients with residual disease demonstrated enhancing lesions on postsurgical MRI.[16,30]

The early scar tissue at the surgical site is highly vascular and will readily uptake contrast on breast MRI. This uptake may be confused with malignancy. Thus, the timing of postsurgical imaging for the most accurate results has been at issue. Frei et al found that MRI performed 28 days or more following surgery provided the greatest sensitivity, specificity, and positive predictive value. Almost half of the patients in this study had false-positive enhancement from foreign body reaction, fat necrosis, or fibrocystic changes. The longer the time between surgery and imaging, the fewer the false-positive results.[31]
Knowing that uptake at the surgical site may be spurious, early imaging to look for additional foci of disease may suffice. If there is concern about residual tumor at the lumpectomy site, then imaging after complete healing has occurred would be preferable (Figure 6). In 26% of patients with positive surgical margins, MRI found additional lesions necessitating a change in treatment plans; 5% had an additional excisional biopsy of the new finding, 4% had a wider surgical excision, and 16.9% had mastectomy instead of planned lumpectomy. Of the 20 patients with falsenegative findings on MRI, 10 underwent wider excision, 8 had a separate excisional biopsy, and 2 had a mastectomy. It is important not only to note the additional cancer found by MRI in these studies, but to realize that more than twice as many additional biopsies were performed and that some patients underwent mastectomy based only on the MRI studies.

Evaluation of patients who have undergone complete or partial mastectomy, with or without myocutaneous flap reconstruction, is difficult. As most of the breast tissue has been removed, the sites of recurrence are beneath the skin or on the chest wall. These areas are hard to image with mammography, and postsurgical changes can be interpreted as suspicious. Generally, no imaging followup is done of the postmastectomy breast unless there is a palpable finding. Rieber et al evaluated patients after mastectomy/lumpectomy and myocutaneous flap reconstruction. MRI did not demonstrate any abnormal contrast uptake and biopsy was avoided in four patients with spiculated masses on mammography. In the four patients with suspicious uptake on MRI, three were false-positives and one had multifocal recurrence. Although the number of patients in this study was small, MRI demonstrated 98% accuracy as opposed to 89% accuracy for mammography and ultrasound.[32]

**Postirradiation Evaluation**

Interpretation of MRI following radiation treatment to the breast can also be challenging. Radiation therapy will slow the healing process and causes diffuse vascular changes that can mimic tumor angiogenesis, producing diffuse contrast uptake that can obscure a malignancy. The associated edema and inflammatory changes can also result in false-positive breast MRI findings. Fewer false-positive results are obtained if imaging is performed after the radiation changes have resolved. The problem has been in determining the optimal time to this status. Morakkabati et al performed MRI exams on patients during and up to 12 months after receiving a total radiation therapy dose of 60 Gy. Radiation changes were identified in the breast with diffuse increased enhancement, but this finding was negated on the subtraction images. Maximum radiation enhancement was seen during radiation treatment, but after 3 months this had subsided and the parenchymal enhancement was similar to the nonirradiated breast.[33]

**Breast Cancer Screening With Contrast-Enhanced MRI**

For a screening test to be useful, it needs to alter the consequence of the disease, not harm healthy subjects, be cost-effective and widely available. Mammography meets these criteria and is the only screening test for breast cancer that has been proven to decrease the risk of breast cancer death. MRI is not sufficiently inexpensive, efficient, or available for population screening. The efficacy of screening mammography has been evaluated in large numbers of women over more than 30 years. Breast MRI is only in its infancy by comparison. So far, only a few screening studies in patients with a strong family history or the BRCA1/2 gene have been completed. Large trials of high-risk patients are being conducted at this time. These high-risk patients are often younger at the time of diagnosis and develop more aggressive tumors. Mammographic screening in younger patients is problematic because their breasts tend to be dense and there is concern for increased lifetime radiation exposure. Dense breast tissue and radiation are not a concern with breast MRI. The published data demonstrate that MRI is more sensitive than mammography for detection of breast cancer in these patients (Table 1). The sensitivity for mammography is 33% to 40%, and for MRI, 79% to 100%. MRI in these investigations has allowed for the detection of an additional 1% to 4% of cancers that would not have been found by conventional means.[34-39]

**Limitations of Screening Breast MRI**

TABLE 1
The Application of Breast MRI in Staging and Screening for Breast Cancer

Although screening breast MRI holds promise for the evaluation of high-risk patients, there are significant limitations of MRI that need to be taken into consideration.

- **Equivocal Findings** - The biggest challenge in mammography, ultrasound, and MRI is the overlap in the imaging appearance between normal tissue and malignant tissue. Benign lesions can appear malignant and vice versa. Unique to contrast-enhanced breast MRI is the fact that the uptake of contrast within normal breast tissue can mimic malignancy and obscure true lesions.

  Kuhl studied 21 healthy volunteers at all stages of the menstrual cycle and found diffuse and nodular enhancement throughout the cycle. A total of 60 enhancing foci were seen, with 73% of these resolving on follow-up imaging.[40] Suspicious MRI uptake has been seen with a variety of benign entities including fibrocystic change, atypical ductal hyperplasia, papillomas, radial scars, atypical lobular hyperplasia, abscesses, mastitis, ductal hyperplasia, fat necrosis, lymph nodes, fibrosis, and sclerosing adenosis.[2,5,7,17,20,31,38]

  These benign lesions can result in incidental enhancing foci in 16% of patients undergoing contrast-enhanced breast MRI.[41] If an incidental finding is seen, the mammogram should be reevaluated and ultrasound directed to that area should be performed. Repeating the MRI at a different stage of the menstrual cycle may resolve the lesion.[40] If the contrast uptake pattern and/or margins are suspicious, MRI-guided biopsy should be considered. Among incidental lesions with a suspicious appearance, 81% have been found to be malignant.[41] Otherwise, follow-up with mammography, sonography, and/or MRI can be performed if the patient does not have a breast carcinoma elsewhere. Incidental lesions with a benign appearance have a 3% to 5%[41,42] incidence of malignancy, and short-term follow-up is an acceptable alternative to breast biopsy. Even in patients with known breast cancer, only 37% of enhancing lesions without a sonographic or mammographic correlate were malignant, whereas 75% of those with a correlate were malignant.[17]

  In screening studies of high-risk patients, the specificity of breast MRI has ranged from 83% to 95%.[34-39] Lower specificity means higher recall and false-positive biopsy rates. The recall rate for mammography in high-risk patients has been found to be 4%,[43] and the recall rate for MRI, 10% to 24%.[34,41,43,44] Abnormalities seen on MRI will prompt additional evaluation with mammography, ultrasound, or repeat MRI. Warren et al found that 16% of patients who were called back underwent more than one additional test.[43] These equivocal MRI findings may delay diagnosis in patients who are more likely to have aggressive tumors.

- **Cost** - Bilateral contrast-enhanced breast MRI costs approximately $1,025.00 whereas bilateral mammography costs $85.00.[45] Thus, a follow-up MRI of a probably benign finding is considerably more expensive than a follow-up mammogram. Approximately 3% to 4% of patients have biopsy for benign lesions seen only on MRI.[34,41] MRI-guided biopsy is considerably more expensive and time-consuming than biopsy with other imaging modalities. When the expense of follow-up studies and biopsies is considered, the cost of finding the 1% to 4%[34-49] of additional cancers with MRI screening may outweigh the benefit.

- **Ductal Carcinoma In Situ** - Another limitation of contrast-enhanced breast MRI is that it can underestimate the presence or extent of ductal carcinoma in situ. The sensitivity for pure ductal carcinoma in situ on contrast-enhanced breast MRI has been reported at 35% to 77%.[4,46,47] This low sensitivity with MRI can be especially troublesome in a mixed lesion of invasive ductal carcinoma and ductal carcinoma in situ, where the extent of the tumor may be underestimated. The common presentation of ductal carcinoma in situ on breast MRI as a regional, linear, or stippled enhancement pattern contributes to the problem.[46,47] The stippled pattern is similar to that seen in fibrocystic change, which is a much more common entity, and distinguishing between these two can be a challenge. Suspicious microcalcifications are the hallmark of ductal carcinoma in situ on mammography, and these can be easily biopsied with stereotactic guidance. MRI has a sensitivity of 45% to 95% in evaluating mammographically clustered calcifications.[47,48] Ductal carcinoma in situ less commonly presents as a mass, which may be smaller than the MRI threshold.[46,47]
• **Other Limitations**—The threshold lesion size seen on contrast-enhanced breast MRI varies depending on technique, equipment, and reader experience. As with mammography, there is a significant learning curve for MRI interpretation. Availability of MRI units is limited, and often there is competition among different radiology subspecialties for allocation of scarce MRI time. Patients with claustrophobia, pacemakers, some cardiac valves, vascular clips, and so forth cannot undergo MRI. Although MRI does not involve radiation, it does use intravenous contrast, and adverse reactions have been seen in 0.06% to 0.1% of patients given intravenous gadolinium contrast.[49,50] Contrast-enhanced breast MRI cannot be performed as quickly as mammography or breast ultrasound. Even with a dedicated MRI unit, only one-third to one-half as many patients can be screened in a day with MRI, as compared with a single mammography unit. If screening breast MRI is performed, then a mechanism must be in place to biopsy suspicious lesions seen only on MRI. Development of open breast coils to allow access has made biopsy easier. MRI-compatible needles and localization wires have been used for several years.[51] A variety of MRI-guided biopsy devices are now on the market, but MRI-guided biopsy poses some problems. The gadolinium may quickly wash out of the breast lesion, making targeting of the lesion difficult. If an MRI-guided presurgical needle localization is done, there is no way to image the specimen to ensure that the lesion was removed.[52] Postoperative MRI is done at some centers to see if the lesion was entirely removed, which adds to the cost of the procedure.[52,53] MRI-guided core biopsy has been found to change the management of 69% to 70% of patients by eliminating the need for surgical biopsy.[54,55]

**The Future of Contrast-Enhanced Breast MRI**

The use of contrast-enhanced breast MRI is growing daily. The data support the use of breast MRI in evaluating patients for occult cancers, extent of disease, and ambiguous mammographic findings. Other uses may prove beneficial, but there are as yet no significant data to confirm this possibility. The lack of standard imaging acquisition technique and interpretation criteria has hindered this research, in that it is hard to replicate findings from institution to institution. The new Breast Imaging Reporting and Data System (BI-RADS) MRI lexicon will allow for a more uniform descriptive terminology, but differences in interpretation may nevertheless persist. Ikeda et al had seven experienced breast MRI imagers evaluate images using the new MRI lexicon. There was substantial or moderate agreement on breast density, lesion type, mass margins, and mass shape but only fair agreement on contrast-enhancement characteristics.[56] New MRI techniques to evaluate the breast are being investigated. Diffusion-weighted MRI imaging measures the mobility of water in tissue. Perfusion-weighted imaging evaluates the rate at which blood is delivered to tissue. These may be used in the future to help differentiate benign from malignant breast MRI findings.[57] Proton MRI spectroscopy may also hold promise in breast evaluation. Spectroscopy measures choline, and it is thought that there are more compounds containing choline in malignant lesions. In one test, MRI spectroscopy demonstrated 89% sensitivity for breast cancer and 100% specificity.[58] The new 3.0 Tesla magnets may result in better signal-to-noise ratios allowing better separation of malignant from benign lesions. Contrast-enhanced breast MRI provides an exciting new adjunct to mammography in the detection of breast cancer. It is not a replacement for mammography. Additional studies need to be performed to determine optimum technique, interpretation criteria, and clinical uses before its full potential can be reliably exploited. Until that time, protocols for traditional diagnosis and treatment of breast cancer should not be abandoned based on these early results.

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