Current Concepts on Preoperative Breast MRI

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After participating in this activity, the radiologist should be familiar with the current indications and controversies of preoperative breast MRI.

CME Category: Breast Imaging
Subcategory: Breast MRI

Key Words: Preoperative Breast MRI, Controversies

It is well established that contrast-enhanced breast MRI is the most sensitive and accurate imaging modality for the local-regional staging of breast cancer. Contrast-enhanced breast MRI is superior to clinical examination, mammography, and ultrasonography, alone or combined, in delineation of the size and extent of the tumor, additional sites of disease, pectoralis muscle and chest wall invasion, nipple and skin involvement, and lymph node metastases.1

Contrast-enhanced breast MRI is the most sensitive and accurate imaging modality for the local-regional staging of breast cancer.

Size and Extent of the Tumor

MRI is the most accurate imaging modality available for the evaluation of the size and extent of breast tumors. Although both under- and overestimations do occur,1 the actual lesion size, as revealed by MRI, correlates best with the pathological size assessment (Figure 1). MRI also is more accurate than mammography or ultrasound for delineating an intraductal component of an invasive cancer (Figure 2).

MRI is the most accurate imaging modality for the evaluation of the size and extent of breast tumors.

Additional Sites of Disease

MRI is superior to conventional imaging for identifying additional breast cancer foci in the same breast as the index tumor, and in the opposite breast. In a meta-analysis of 19 studies evaluating preoperative breast MRI, MRI detected otherwise occult cancers in the ipsilateral breast in 16% of cases (Figure 3).2 In a meta-analysis of 22 studies, MRI found additional cancer in 4.1% of patients in the contralateral breast at the time of diagnosis (Figure 4).

MRI is superior to conventional imaging for identifying additional breast cancer foci in the same breast as the index tumor, and in the opposite breast.

Pectoralis Muscles and Chest Wall Invasion

The pectoral muscles and chest wall are better evaluated by MRI than by mammography or ultrasound for detection of tumor invasion. Infiltrative or mass-like contrast enhancement of these structures is the only reliable MRI finding to predict invasion (Figures 5 and 6). The obliteration of fat planes alone does not indicate invasion. Tumors with chest wall invasion may require preoperative chemotherapy.

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and/or radiation, possibly followed by chest wall resection. However, a tumor invading the pectoral muscle may only require partial or complete resection of the muscle.\(^1\)

**Infiltrative or mass-like contrast enhancement is the only reliable MRI finding to predict invasion of the pectoral muscles and chest wall.**

**Nipple and Skin Involvement**

Malignant involvement of the skin may be seen in inflammatory breast carcinoma resulting from tumor micrometastases within dermal lymphatics; or, in the case of locally advanced breast cancer, from direct skin invasion by an underlying tumor. Skin thickening and enhancement are signs of skin involvement, often contiguous with an underlying malignancy. Unilateral nipple enhancement on breast MRI is suggestive of malignant nipple involvement,
supraclavicular nodes, most of the regional nodes, including ipsilateral axillary (levels I–III), internal mammary, and intramammary nodes, are in the field of view on breast MRI (Figure 7). Features suggesting a nodal metastasis include loss of the fatty hilum, increased cortical thickness (>3 mm), focal cortical thickening, irregular margins, edema surrounding the node, and asymmetry of these features compared with the opposite axilla. Any visualized internal mammary node, especially when larger than 5 mm, should be regarded as suspicious for metastasis.1

 Except for the supraclavicular nodes, most of the regional nodes are in the field of view on breast MRI.

Unilateral nipple enhancement on breast MRI is suggestive of malignant nipple involvement, especially when the nipple is contiguous with the underlying tumor.

Regional Lymph Nodes
The detection of regional lymph node metastases is an important part of breast cancer staging. Except for the especially when the nipple is contiguous with the underlying tumor (Figure 5). Involvement of the nipple by underlying malignancy is an important factor in surgical planning, as it requires resection of the nipple-areola complex, usually with mastectomy.1

Figure 2. A 59-year-old woman with a large palpable left breast mass. A: This left ML mammographic view shows a large, ill-defined focal asymmetry at the 12:00 location (between arrows), corresponding to the palpable mass. The tissue marker and overlying skin changes are related to a recent percutaneous core biopsy. A sonogram revealed 3 adjacent ducts distended with hypoechoic tissue or debris (not shown). B: Breast MRI was performed because of the discrepancy of tumor size among the clinical examination, mammography, and ultrasound. This sagittal, postcontrast, fat-saturated, T1-weighted MIP MR image shows a large area of clumped nonmass enhancement in the central upper breast (between arrows), with rapid and mixed, plateau/washout kinetics (not shown). Simple mastectomy confirmed extensive DCIS without an invasive focus.

especially when the nipple is contiguous with the underlying tumor (Figure 5). Involvement of the nipple by underlying malignancy is an important factor in surgical planning, as it requires resection of the nipple-areola complex, usually with mastectomy.1
Subsets of Patients Likely to Benefit From Preoperative Breast MRI

The subsets of patients most likely to benefit from preoperative breast MRI are:

- Patients with dense breast tissue, because tumor visualization in these patients tends to be hindered on mammography;
- Patients with invasive lobular carcinoma, because these tumors tend to be multiple and bilateral;
- Patients with posterior breast cancer, for detection of pectoral muscles and chest wall invasion;
- Patients planning to undergo partial breast irradiation, because patients with multiple tumors are not fully treated with partial breast irradiation and, therefore, are not appropriate candidates for this type of therapy; and
- High-risk patients, such as patients with genetic alterations (BRCA1 and BRCA2 mutations) or a history of mantle chest radiation because these patients are at high risk for multiple and bilateral breast cancers.

Other clinical scenarios for which preoperative breast MRI is useful include:

- Known multifocal, multicentric or bilateral disease;
- Metastatic axillary lymphadenopathy of unknown primary malignancy and a negative mammogram;
- Positive surgical margins after initial lumpectomy and before reoperation, to evaluate residual tumor burden;
- Paget disease of the nipple without findings on conventional breast imaging;
- Monitoring patients undergoing neoadjuvant chemotherapy; and
- Discordant findings between clinical examinations and imaging, or between imaging modalities, especially with size discrepancy of greater than 10 mm between mammography and ultrasound.
Based on the previous discussion, the anticipated clinical benefits of preoperative breast MRI include decreased positive surgical margins and reexcision rates; better stratification of patients for breast conserving therapy (BCT) versus mastectomy; decreased local recurrence rates by resecting otherwise occult multifocal or multicentric tumors; and decreased metachronous contralateral cancer rates by simultaneous detection and treatment of contralateral tumors. However, the clinical outcome studies evaluating the actual overall benefit of MRI show conflicting results. Controversy over the use of preoperative breast MRI has focused on the issues of delay in definitive therapy, reexcision rates, mastectomy rates, and long-term survival impact.3

Delay in Definitive Therapy

Two studies have shown treatment delays of 17 to 22.4 days in the group of patients undergoing preoperative breast MRI. However, Hollingsworth and Stough4 asserted that all of their patients completed MRI work-up before the surgeon’s first open clinic date; hence there was no delay in treatment. The potential delay is attributed to the detection of additional lesions by MRI, necessitating additional imaging and biopsy. Although the delay is unlikely to affect patient survival, it is felt to contribute to the cost of care and patient anxiety. To minimize delay, it is imperative that facilities that offer breast MRI have the commitment and capability to complete evaluation and biopsy of MRI-detected lesions promptly. If not, they should have

Figure 5. A 61-year-old woman with a posterior right breast cancer. This axial, postcontrast, fat-saturated, T1-weighted MR image demonstrates an enhancing spiculated mass (T), the known cancer, invading the underlying pectoral muscle. Ductal enhancement (triple small arrowheads) extends from the mass anteriorly, to involve the nipple (short, thick arrow). Note the intense enhancement with mild retraction and lateral deviation of the nipple. Also note the involvement of the skin in the lateral breast by tumor, evidenced by diffuse thickening and enhancement (triple arrows).

Figure 6. A 65-year-old woman with locally advanced left breast cancer. A: This axial, postcontrast, fat-saturated, T1-weighted MR image shows the contracted left breast with multiple, confluent enhancing tumors (T). Diffuse enlargement and enhancement of the left pectoralis major muscle (PM) and pectoralis minor muscle (thin white arrow) indicate invasion. Invasion of the right pectoral muscle (black arrow) and parasternal soft tissues is seen. Enhancing pleura (single thick white arrow) and pericardium (double white arrows) suggest tumor involvement. Extensive skin thickening and enhancement on the left indicate skin invasion. Thickened skin with nodular enhancement and underlying clumped nonmass enhancement extend across the midline to involve the right breast (between curved arrows). B: This sagittal, postcontrast, T1-weighted MR image illustrates enhancement of the intercostal muscles (triple arrows) consistent with chest wall invasion. Also note the invasion of the pectoralis major muscle (long thick arrow) and the overlying skin (short thick arrow) by tumor (T).
decreased reexcision rates in patients with preoperative breast MRI, while studies 7 to 11 showed no benefit in the MRI group. Many of these retrospective studies undoubtedly have patient selection bias by performing more MRIs on patients at higher risk for positive margins. MRI may have reduced the reexcision rates in these patients to the same level as the lower risk (no MRI) group, therefore an established referral arrangement with an experienced breast center to provide these services.

Conflicting Data on Reexcision Rates

There are conflicting results among the outcome studies on reexcision rates with and without preoperative breast MRI (Table 1). As shown in Table 1, studies 1 to 6 showed decreased reexcision rates in patients with preoperative breast MRI, while studies 7 to 11 showed no benefit in the MRI group. Many of these retrospective studies undoubtedly have patient selection bias by performing more MRIs on patients at higher risk for positive margins. MRI may have reduced the reexcision rates in these patients to the same level as the lower risk (no MRI) group, therefore

Table 1. Outcome Studies: The Impact of Preoperative Breast MRI on Reexcision Rate

<table>
<thead>
<tr>
<th>Studies</th>
<th>Lead Author</th>
<th>Journal</th>
<th>Type of Study</th>
<th>No. of Patients</th>
<th>Reexcision Rate With MRI</th>
<th>Reexcision Rate, No MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hollingsworth</td>
<td>Am J Surg 2008</td>
<td>Retrospective</td>
<td>603</td>
<td>8.8%</td>
<td>No control</td>
</tr>
<tr>
<td>2</td>
<td>Pengel</td>
<td>Breast Cancer Res Treat 2008</td>
<td>Retrospective</td>
<td>349</td>
<td>All 13.8%, IDC 1.6%</td>
<td>All 19.4%, IDC 8.1%</td>
</tr>
<tr>
<td>3</td>
<td>McGhan</td>
<td>Ann Surg Oncol 2010</td>
<td>Retrospective</td>
<td>70 ILC</td>
<td>4.17%</td>
<td>9.17%</td>
</tr>
<tr>
<td>4</td>
<td>Mann</td>
<td>Breast Cancer Res Treat 2010</td>
<td>Retrospective</td>
<td>267 ILC</td>
<td>9%</td>
<td>27%</td>
</tr>
<tr>
<td>5</td>
<td>Allen</td>
<td>Ann Surg Oncol 2010</td>
<td>Retrospective</td>
<td>98 DCIS</td>
<td>21.2%</td>
<td>30.8%</td>
</tr>
<tr>
<td>6</td>
<td>Obdeijn</td>
<td>AJR Am J Roentgenol 2013</td>
<td>Retrospective</td>
<td>123</td>
<td>18.9%</td>
<td>37.4%</td>
</tr>
<tr>
<td>7</td>
<td>Bleicher</td>
<td>J Am Coll Surg 2009</td>
<td>Retrospective</td>
<td>577</td>
<td>21.6%</td>
<td>13.6%</td>
</tr>
<tr>
<td>8</td>
<td>Hwang</td>
<td>Ann Sur Oncol 2009</td>
<td>Retrospective</td>
<td>472</td>
<td>11.3%</td>
<td>13.3%</td>
</tr>
<tr>
<td>9</td>
<td>Weber</td>
<td>Arch Surg 2012</td>
<td>Retrospective</td>
<td>313</td>
<td>19.1%</td>
<td>17.6%</td>
</tr>
<tr>
<td>10</td>
<td>Wang</td>
<td>Breast Cancer Res Treat 2013</td>
<td>Retrospective</td>
<td>45,453</td>
<td>25.7%</td>
<td>20.5%</td>
</tr>
<tr>
<td>11</td>
<td>Houssami</td>
<td>Ann Surg 2013</td>
<td>Meta-analysis</td>
<td>3,112 (9 studies)</td>
<td>All 11.6%, ILC 10.9%</td>
<td>All 11.4%, ILC 18.0%</td>
</tr>
<tr>
<td>12</td>
<td>Turnbull et al.</td>
<td>Lancet 2010</td>
<td>Prospective randomized</td>
<td>1,623</td>
<td>18.75%</td>
<td>19.33%</td>
</tr>
<tr>
<td>13</td>
<td>Peter et al.</td>
<td>Eur J Cancer 2011</td>
<td>Prospective randomized</td>
<td>418</td>
<td>34%</td>
<td>12%</td>
</tr>
</tbody>
</table>

DCIS, ductal carcinoma in situ; IDC, invasive ductal carcinoma; ILC, invasive lobular carcinoma.
masking the benefit of MRI. It is important to note that studies 3, 4, and 11 showed consistent reduction of reexcision rates in patients with invasive lobular carcinoma (ILC) undergoing preoperative breast MRI.

The recently published Comparative Effectiveness of MRI in Breast Cancer (COMICE) and MR Mammmography of Nonpalpable Breast Tumors (MONET) trials are prospective studies (studies 12 and 13, respectively; Table 1). The COMICE trial found no difference in reexcision rates between patients with or without MRI. This trial, conducted in the United Kingdom, involved 45 breast centers of widely varied expertise in breast MRI. Because the UK national health policy mandates reoperation rates for positive margins to be under 10%, the very wide excisions routinely performed in the UK during lumpectomy could have negated the benefit of MRI. The MONET trial found a paradoxical increase in reexcision rates in patients with MRI (34% MRI vs. 12% no MRI). This trial focused on nonpalpable breast cancers, resulting in 60% of the lesions being ductal carcinoma in situ (DCIS) identified as microcalcifications only, which is not as well evaluated by MRI as invasive cancer. The mean volume of excised tissue in the MRI group was smaller than in the non-MRI group (69.1 cm³ vs. 90.2 cm³). It was even smaller in patients with DCIS and a negative MRI (40.3 cm³). These findings are the most likely explanation for the paradoxically higher rates of positive margins and reexcision.

Mastectomy Rate

MRI has been criticized for overestimation of tumors leading to pathologically unjustified mastectomies or wider excisions. A meta-analysis of 19 studies on the impact of MRI on surgical planning showed a conversion rate of 1.1% from BCT to mastectomy and a conversion rate of 5.5% to more extensive excision because of false-positive MRI findings. These pathologically unjustified surgeries are avoidable in modern practice with the availability of MRI-guided biopsy. It is important that any change in surgical management should be based on biopsy proof of more extensive disease, not just suspicious imaging findings. The analysis showed pathologically justified conversions from BCT to mastectomy in 8.1% of cases, which roughly equals the 10-year local recurrence rate. It is possible that MRI selects the women destined for recurrence and converts their treatment to mastectomy at the time of initial surgery.

Although some studies linked an increasing mastectomy rate to preoperative MRI, others reported increased BCT rates among patients with MRI, due to its high negative predictive value. A study at Mayo Clinic reported that the mastectomy rate in the United States increased from 29% to 41% between 2004 and 2006, mostly among patients without MRI. McGuire and associates also showed MRI to have no impact on the mastectomy rate. It is increasingly clear that the national trend of increasing mastectomies is multifactorial and mostly patient driven. The availability of skin- and nipple-sparing mastectomy with reconstruction and good cosmetic results, the ability to identify women at high risk for tumor recurrence, better understanding of the late effects of breast radiation, and patients’ increased knowledge about their disease and options may all contribute to this trend.

Survival Impact

Currently, the impact of preoperative MRI on survival after BCT is uncertain because of the lack of long-term outcome data. Three retrospective studies of the impact of MRI on the local recurrence rate, which may influence long-term survival, showed conflicting results. Because of the current low rates of local recurrence after BCT, and low contralateral cancer rates, opponents of preoperative MRI question the benefit of finding additional cancer foci because these foci should be treated effectively with whole breast radiation and systemic therapy, and may be clinically insignificant. However, the International Breast MRI Consortium 6883 study showed that cancers found only on MRI were similar in size and histology to cancers detected on mammography, but had a higher likelihood of being higher grade. Hence there is no basis to assume that the additional MRI-detected cancers are biologically inert, are clinically irrelevant, or will be treated adequately by standard therapies used in BCT. Furthermore, the increasing use of partial breast radiation places even greater significance on these additional cancers, which will remain potentially untreated.

Conclusion

This CME activity emphasizes that MRI is the most accurate modality for local-regional staging of breast cancer. Findings of multifocal, multicentric, and contralateral tumors help guide surgical planning and decisions on adjuvant therapy. MRI is beneficial in a subset of women, particularly those with large tumors, dense breast tissue, or invasive lobular cancer. Many studies show that preoperative breast MRI reduces reexcision rates, although no increased survival benefit has been proven. The clinical outcome studies to date have limitations and are not generalizable to modern breast MRI practice. A well-designed prospective randomized controlled trial on the short- and long-term benefits of preoperative breast MRI is needed and is currently under development by the American College of Radiology Imaging Network (ACRIN).

References

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1. Which one of the following is the only reliable breast MRI finding to predict pectoral muscle invasion by breast cancer?  
   A. Obliteration of the fat plane between the cancer and the pectoral muscle  
   B. Increased vascularity between the cancer and the pectoral muscle  
   C. Expansion of the pectoral muscle  
   D. Contrast enhancement of the pectoral muscle  
   E. Tumor abutting the pectoral muscle

2. Which of the following is/are controversies concerning the use of preoperative breast MRI in a newly diagnosed patient with breast cancer?  
   A. Conflicting results of reexcision rates  
   B. Associated increased mastectomy rates  
   C. Consequent delay in definitive therapy  
   D. No proof of long-term survival benefit  
   E. All of the above

3. In staging of breast cancer, all of the regional lymph nodes are in the field of view on breast MRI, except  
   A. intramammary nodes  
   B. supravacular nodes  
   C. ipsilateral axillary level I nodes  
   D. ipsilateral axillary level II nodes  
   E. ipsilateral axillary level III nodes

4. Figure 8 is an axial, postcontrast, fat-saturated, T1-weighted breast MR image of a 63-year-old woman with a markedly deformed left breast. The most likely diagnosis is  
   A. invasion of the pectoralis major muscle by a left breast cancer  
   B. invasion of the chest wall by a left breast cancer  
   C. invasion of the pericardium by a left breast cancer  
   D. invasion of the pleura by a left breast cancer  
   E. no evidence of skin involvement by a left breast cancer

5. Which one of the following subsets of patients is least likely to benefit from preoperative breast MRI?  
   A. A patient with dense breast tissue  
   B. A patient with a posteriorly located breast cancer  
   C. A patient planning to undergo partial breast irradiation  
   D. A patient planning mastectomy to treat recurrent breast cancer  
   E. A patient undergoing neoadjuvant chemotherapy

6. For which one of the following clinical scenarios is preoperative breast MRI most useful for treatment planning of breast cancer?  
   A. Metastatic axillary lymphadenopathy in a patient with known breast cancer  
   B. Paget disease of the nipple, with a subareolar spiculated mass on mammogram  
   C. Monitoring the patient who will be treated with lumpectomy without chemotherapy  
   D. Positive surgical margins after initial lumpectomy and before reoperation  
   E. Concordant findings between clinical examinations and multimodality imaging

7. Which one of the following breast cancer types shows a reduction in postlumpectomy reexcision rates when breast MRI had been performed preoperatively?  
   A. Invasive lobular carcinoma  
   B. Invasive ductal carcinoma  
   C. Mucinous carcinoma  
   D. Metaplastic carcinoma  
   E. None of the above

8. All of the following patients are at high risk for multifocal and bilateral breast cancers, except  
   A. a patient with a history of prior mantle radiation therapy  
   B. a patient with the BRCA1 mutation  
   C. a patient with the BRCA2 mutation  
   D. a patient with inflammatory breast cancer  
   E. a patient with invasive lobular carcinoma

9. Which one of the following is the most sensitive and accurate imaging modality for the local-regional staging of breast cancer?  
   A. Digital mammography  
   B. Whole-breast ultrasound  
   C. Contrast-enhanced breast MRI  
   D. Breast elastography  
   E. Digital breast tomosynthesis

10. In which one of the following imaging modalities does the actual size of a breast cancer correlate best with its pathological size assessment?  
    A. Digital mammography  
    B. Whole-breast ultrasound  
    C. Contrast-enhanced breast MRI  
    D. Breast elastography  
    E. Digital breast tomosynthesis