Delineating Extramammary Findings at Breast MR Imaging

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Abbreviations: FDG = fluorine 18 fluorodeoxyglucose, PPV = positive predictive value, STIR = short inversion time inversion-recovery

RadioGraphics 2017; 37:10–31
Published online 10.1148/rg.201760051
Content Codes: BR CH MR 01

Breast magnetic resonance (MR) imaging is the only breast imaging modality that consistently encompasses extramammary structures in the thorax and upper abdomen. Incidental extramammary findings on breast MR images of patients with a history of breast cancer or other malignancies are significantly more likely to be malignant and may affect staging and treatment. An understanding of the frequency, distribution, and context of extramammary findings on breast MR images and a familiarity with common and uncommon sites of breast cancer metastasis inform the differential diagnosis and prompt the appropriate diagnostic next step, to differentiate benign from malignant findings. High-yield organ systems on breast MR images, as reflected by a high positive predictive value for malignancy, are correlated with known distant sites of breast cancer metastasis in the bone, lung, liver, and lymph nodes. Staging is considered when disease involves the skin and chest wall. Unusual sites of breast cancer metastasis from invasive lobular carcinoma are discussed, including the gastrointestinal tract, peritoneum, and adrenal glands. Nonmalignant clinically important findings involving the cardiovascular and gastrointestinal systems are reviewed, and potential pitfalls in diagnosis and interpretation are highlighted. A consistently systematic diagnostic approach is emphasized for identifying extramammary abnormalities on breast MR images. All things considered, the radiologist should be able to improve diagnostic sensitivity and specificity while interpreting extramammary findings on breast MR images.

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SA-CME LEARNING OBJECTIVES
After completing this journal-based SA-CME activity, participants will be able to:
- Recognize that incidental extramammary breast MR imaging findings are most likely to be clinically relevant in those with a history of breast or other malignancy.
- Explain the frequency and distribution of extramammary findings at breast MR imaging and their positive predictive values for malignancy.
- Describe common and uncommon sites of breast cancer metastasis to extramammary organ systems depicted on breast MR images.

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Introduction
The challenge of dealing with incidental imaging findings is not a new one. Breast magnetic resonance (MR) imaging, with its superior soft-tissue resolution and larger field of view, is the only breast imaging modality to consistently capture extramammary structures. Findings in these structures are often important, because breast MR imaging is primarily performed for breast cancer staging and high-risk screening. Even as the use of breast MR imaging increases with time (1), further workup of incidental extramammary findings has been shown to be of value and cost effective (2). Overall, 16.8%–34% of breast MR imaging examinations demonstrate extramammary findings, and 18.1%–20.4% of these findings are malignant (2–4). In particular, 46%–82% of patients undergoing breast MR imaging have either newly diagnosed breast cancer or a personal history of a previous diagnosis of breast cancer (4–6); and extramammary findings are more likely to be malignant in these patients than in others (7,8). As such, it is essential
Figure 1. Drawing shows various sites of breast cancer metastasis. The most common sites of breast cancer metastasis include the bones, lungs, liver, lymph nodes, and brain—the first four of which are routinely depicted on breast MR images—and require careful systematic evaluation.

Common Distant Sites of Metastasis

**Bones**

*Breast Cancer Metastasis: High Propensity for Bones.*—The bones are the most common site of breast cancer metastasis, and metastasis to bone is found in approximately 60% of the women with...
metastatic disease (10,12,14) (Table 1). Those with bone metastases from breast cancer have a median survival of 33.2 months (15). The bones also represent the most common exclusive first site of disease spread in women with early-stage (stages I and II) breast cancer after treatment with breast conservation therapy and whole-breast radiation therapy, with such spread often manifesting 10–15 years after the initial diagnosis of breast cancer (9). This observation highlights the importance of careful evaluation of osseous structures at surveillance breast MR imaging examinations, particularly given the high PPV of 64% for bone findings depicted on breast MR images (Table 2) (4,5,7,8). Of interest, triple-negative breast cancers (particularly the basal-like subtype) metastasize to the bones significantly less frequently ($P < .001$) (10) than other subtypes (10,16) (Table 1), although still with a high enough metastatic rate to the bone (39% for the basal-like subtype) to warrant careful osseous evaluation.

**Evaluation of the Bones.** —Although coverage of the spine is variable, depending on the chosen field of view, the midline anterior osseous structures (manubrium, sternum, and xiphoid process) (Fig 2) and the ribs are usually depicted and should be scrutinized with T1-weighted sequences before and after contrast material administration (for abnormal signal intensity and enhancement) and with T2-weighted sequences (for marrow edema) to assess for osseous metastases (Fig 3). Multiple lesions and associated soft-tissue masses are highly suggestive of metastases. Evaluation of diffuse osseous involvement is often challenging and requires an understanding of normal bone marrow signal intensity on MR images to determine a correct diagnosis. Bone findings can be subtle on breast MR images and thus warrant consistent inclusion in the search pattern (Fig 3). The spine is far posterior in the field of view on breast MR images on both sagittal and axial projections, and partially depicted abnormalities are easy to miss. Therefore, multiplanar correlation and assessment with multiple imaging sequences are helpful. Occasionally, benign intraosseous hemangiomas are depicted in the spine or in the sternum as circumscribed

| Table 1: Frequency of Site-specific Metastasis by Subtypes of Metastatic Breast Cancer |
|-------------------------------|-------------------|-------|-------|-------|-------|
| Subtype of Metastatic Breast Cancer | Frequency of Site-specific Metastasis (%) |       |       |       |       |
| Luminal A | 66.6 | 23.8 | 28.6 | 7.6  | 15.9 |
| Luminal B | 71.4 | 30.4 | 32.0 | 10.8 | 23.3 |
| HER2 positive, ER/PR positive | 65.0 | 36.8 | 44.4 | 15.4 | 22.2 |
| HER2 positive, ER/PR negative | 59.6 | 47.1 | 45.6 | 28.7 | 25.0 |
| Basal-like | 39.0 | 42.8 | 21.4 | 25.2 | 39.6 |
| TN nonbasal | 43.1 | 35.8 | 32.1 | 22.0 | 35.8 |
| Overall frequency | 57.5 | 36.1 | 34.0 | 34.5 | 27.0 |

Note.—Adapted, with permission, from reference 10. ER = estrogen receptor, HER2 = human epidermal growth factor receptor 2, PR = progesterone receptor, TN = triple negative.

| Table 2: PPVs of Extramammary Findings on Breast MR Images |
|--------------------------|-----------------|-----------------|-----------------|-----------------|
| Study                    | Year            | PPV (%) Bone | PPV (%) Lung | PPV (%) Liver | PPV (%) Nodes* |
| Rinaldi et al (4)        | 2011            | 89            | 59            | 9              | 83             | 1535            |
| Morakkabati-Spitz et al (8) | 2003           | 73            | 100           | 8              | 81             | 1013            |
| Iodice et al (5)         | 2013            | 26            | 17            | 2              | 21             | 828             |
| Moschetta et al (7)      | 2014            | 66            | 83            | 0              | NA†            | 308             |
| Overall PPV              |                | 64            | 65            | 5              | 62             | 3684‡           |

*Nodes category does not differentiate between regional and distant nodal metastases.
†NA = not applicable (because no nodal lesions were reported in this study).
‡Total number of examinations.
Figure 2. Osseous metastasis in a 52-year-old woman with newly diagnosed invasive ductal carcinoma in the right breast. Axial (a) and sagittal (b) contrast-enhanced T1-weighted MR images show an enhancing lesion (arrow) in the sternum, a finding consistent with an osseous metastasis. On breast MR images, midline osseous lesions are often found in the sternum, manubrium, and xiphoid process.

Figure 3. Osseous metastases in a 40-year-old woman with newly diagnosed cancer in the left breast who underwent breast MR imaging to evaluate the disease extent. (a, b) Axial T2-weighted (a) and contrast-enhanced T1-weighted subtraction (b) MR images show edema and subtle abnormal enhancement in multiple bilateral ribs and the sternum (solid arrow), findings that were highly suspicious for osseous metastases. An anterolateral left rib was fractured (dashed arrow). The findings from a subsequent bone scan helped confirm diffuse metastases (not shown). Computed tomography (CT) was performed to exclude pathologic fractures involving the spine. (c) Coronal CT image shows diffuse osseous metastases involving the spine, manubrium, sternum, pelvis, and ribs. CT helped confirm the pathologic fracture of the anterolateral left rib (not shown).

When the morphologic structure is atypical, a bone scan is often required to exclude the possibility of an osseous metastasis.

Overlap of Benign and Malignant Findings.—Breast cancer survivors are prone to osteoporosis and fractures (17,18). This tendency is due to direct bone depletion or premature ovarian failure related to chemotherapy and endocrine therapy or is secondary to prophylactic oophorectomy. In
older women, a baseline higher risk of osteoporosis is further exacerbated by the posttreatment effects of therapy with aromatase inhibitors. As such, both benign and malignant fractures are common in this group. Although imaging features suggestive of benign fractures compared with malignant fractures have been described on MR images, differentiating between the two is not always possible (19,20). For that reason and because osseous metastases are highly prevalent in breast cancer patients (approximately 60%) (10), bone findings on breast MR images in the setting of a history of breast cancer warrant careful exclusion of metastasis, despite the likely benign causes (Fig 5).

**Lungs**

**Physiologic versus Pathologic Pleural Effusions.**—Pleural effusions are common findings on breast MR images, with physiologic pleural effusions reported in 87% of healthy subjects undergoing screening breast MR imaging (6), which may account for the low PPV for malignancy (6%) reported in the literature (4). However, the pleural space is a known location of breast cancer metastasis, with the investigators in one study reporting the pleural space to be the site of breast cancer metastasis 31.2% of the time when combined with the peritoneal space (10). Thus, malignant effusions must be distinguished from physiologic effusions. Investigators have shown physiologic pleural effusions to be more commonly bilateral (71%) and, when unilateral, more frequently right sided than left sided, with a normal reference size range of up to 7 mm on the right and up to 5 mm on the left (6). In contrast, a malignant pleural effusion tends to be unilateral and moderate to large in size (size refers to maximum depth of fluid measured from the posterior chest wall on axial projection) (Fig 6), with the patient usually having a clinical history of current or prior breast cancer. In this scenario, adjacent anatomic structures must be scrutinized to assess for metastasis (Fig 6). Occasionally, a benign but clinically important pleural effusion may be depicted, which requires further identification of its benignity (Fig 7). In short, a moderate to large unilateral pleural effusion depicted on breast MR images, particularly in a patient with a history of breast cancer, warrants careful further evaluation to exclude a malignant cause.

**Common Benign Pulmonary Findings.**—Breast conservation therapy comprises surgical excision followed by whole-breast radiation therapy. Because the radiation beam traverses the entire path of the treated breast, lung tissue is affected. After radiation therapy (typically 30–40 Gy), early lung injury (at 6–8 weeks) manifests as radiation pneumonitis (worst at 3–4 months) and becomes stable radiation-induced fibrosis by 9–12 months (21,22) (Fig 8). Radiation pneumonitis appears as patchy consolidations or signal intensity abnormalities in the lung that are confined within sharp margins conforming to the radiation portal. Radiation-induced fibrosis is more frequently depicted on breast MR images because most patients do not typically begin MR imaging surveillance until 1 year after...
Figure 5. Incidental left rib fracture on surveillance breast MR images in a 71-year-old woman with a remote history of cancer in the right breast. (a) Axial contrast-enhanced T1-weighted MR image shows incidental findings of a left rib fracture (solid arrow), as well as a large hiatal hernia (dashed arrow). At a recent prior examination with dual-energy x-ray absorptiometry, the T-score was –2.8. (b) Sagittal scout image shows a midthoracic subacute burst fracture (arrow). Further inquiry of the patient disclosed a history of a fall, which helped confirm the diagnosis of a traumatic rib fracture in this patient with osteoporosis. Nevertheless, given her history of breast cancer, bone scintigraphy was performed to rule out osseous metastasis, and the findings were negative.

Figure 6. Incidental pleural effusion at the first surveillance MR imaging examination in 5 years in a 50-year-old woman with a history of cancer in the left breast who had undergone bilateral mastectomy. (a) Axial T2-weighted MR image shows a moderate right-sided pleural effusion (arrow). (b) Coronal contrast-enhanced T1-weighted subtraction MR image shows an enhancing right parasternal metastasis involving multiple intercostal spaces (arrows) and inciting a malignant pleural effusion.

treatment. Radiation-induced fibrosis appears as a subpleural linear band of enhancement in the lung, often with frayed edges (Fig 8). Once stable radiation-induced fibrosis is established on annual breast MR images, any further increase or change in appearance beyond 1–2 years after radiation therapy should prompt consideration of superimposed infection or tumor recurrence. In contrast, dependent atelectasis, another common benign pulmonary finding on breast MR images, is transient. This finding is depicted as a signal intensity abnormality in a linear or triangular configuration with concave margins (Fig 9) that is located anteriorly in a prone patient, indicating dependent collapse of normal lung tissue, and is of no clinical consequence.

Evaluation of the Lungs.—The lungs are a common site of breast cancer metastasis (36.1%), not to mention primary lung cancer, and pulmonary findings on breast MR images carry a high PPV of 65% (Tables 1, 2) (4,5,7,8,10). A patient with breast cancer metastasis to the lung has an expected median survival of 22.4 months (15). Therefore, the lung should be scrutinized on breast MR images. Careful adjustment of window level settings is often
Figure 7. Incidental pleural effusion on breast MR images in a 62-year-old woman who had benign findings at prior left breast surgery. (a) Axial short inversion time inversion-recovery (STIR) MR image shows an incidental finding of a right-sided pleural effusion (arrow) that was slightly larger than expected for physiologic fluid. Further evaluation was performed. (b) Axial STIR MR image obtained subsequently shows a right middle lobe pulmonary consolidation (arrow), which was causing a secondary effusion. The patient reported a mild cough and was subsequently treated for pneumonia.

Figure 8. Radiation-induced fibrosis in a 52-year-old woman with a history of invasive ductal carcinoma of the right breast who had been treated with bilateral mastectomy with transverse rectus abdominis myocutaneous (TRAM) flap reconstruction and radiation therapy of the right breast 5 years previously. Axial contrast-enhanced T1-weighted (a) and sagittal contrast-enhanced T1-weighted subtraction (b) MR images show a stable linear right-sided subpleural area of enhancement (arrows) with frayed edges, findings consistent with radiation-induced fibrosis.

necessary to depict pathologic conditions, because the lung is not optimally displayed with the default breast MR imaging parameters (Fig 10a). On the other hand, with improvements in the breast MR imaging technique and resolution, even subtle findings in the lung are able to be seen if viewing conditions are optimized (Fig 11). The central, pericardial, and perihilar region and the peripheral regions of the lungs are prone to degradation by cardiac and respiratory motion and should be carefully evaluated on all available projections (Fig 10c, 10d). To further define pulmonary findings depicted on breast MR images, cross-modality correlation with images from prior examinations is helpful, often allowing confirmation of stable benign lesions (Fig 12). Chest CT is the reference standard for evaluating pulmonary findings. If no prior chest images are available, chest CT is appropriate for further evaluation, particularly in the setting of a history of breast cancer.

Liver

Importance of Liver Evaluation. — Focal liver lesions are the most common extramammary findings on breast MR images, accounting for 44%–52% of these findings (2,4,5). Although the PPV of focal liver lesions on breast MR images is only 7% (4), the liver is, in fact, a common metastatic site not only for breast cancer (34%)
(Table 1) (10), but also for many other malignancies, including those of the gastrointestinal tract, lungs, and skin. Identifying a liver metastasis is important, because it indicates a poor prognosis. On average, the reported median survival of patients with metastatic breast cancer to the liver is only 12 months (15). The low PPV of liver lesions on breast MR images may in part be explained by incomplete hepatic imaging on breast MR images and by a high prevalence of benign hepatic lesions such as cysts or hemangiomas, which are not only common but also particularly prevalent among women (23,24). Therefore, despite the low PPV of liver lesions on breast MR images (4), the liver requires careful evaluation to exclude the possibility of metastasis. Note that the liver is imaged to a variable extent on axial, sagittal, and coronal projections, and focal lesions may be partially imaged or only depicted on one projection.

Cystic Liver Lesions.—Hepatic cysts are exceedingly common and in most cases can be confidently diagnosed on breast MR images; hepatic cysts are seen as T2-hyperintense, well-circumscribed thin-walled nonenhancing masses (Fig 13). For cystic hepatic lesions that may be too small to fully characterize on MR images, cross-modality correlation to CT or ultrasonographic (US) images and comparison with images from prior examinations are helpful to confirm a benign cause. Occasionally seen, diffuse, scattered, T2-hyperintense nonenhancing hepatic lesions measuring less than 1.5 cm throughout the liver may also represent biliary hamartomas (also known as von Meyenburg complexes), which are remnants of embryonic bile ducts. However, hepatic cysts are far more common than biliary hamartomas. It is essential to assess T2-hyperintense liver lesions depicted on breast MR images with contrast-enhanced breast MR images for a complete evaluation. Although the exact PPV of cystic liver lesions on breast MR images is unknown, cystic metastases from breast, ovarian, lung, and colorectal cancer, sarcoma, and melanoma do occur because of necrosis and cystic degeneration, and these cystic metastases usually demonstrate less-circumscribed margins with enhancing components on MR images (23,25).

Solid Liver Lesions.—The most common solid liver lesions are metastases. Among women with metastatic breast cancer, liver metastases are found 34% of the time (Table 1) (10). The appearance of metastatic lesions in the liver is highly variable but can be T1 hypointense and moderately T2 hyperintense, with washout on delayed contrast-enhanced images (26). Hemangiomas are the second most common solid liver lesions seen on breast MR images, because they are most prevalent in women, particularly in postmenopausal women. On breast MR images, the typical enhancement pattern of initial peripheral nodular and progressive centripetal enhancement clinches the diagnosis (Fig 14); but when this pattern is absent, metastasis must be excluded. In fact, any previously unevaluated solid liver lesion should undergo dedicated liver imaging including CT or MR imaging for further evaluation, unless the typical enhancement pattern of a hemangioma is seen. Because the liver is seldom imaged in its entirety on breast MR images, partially imaged findings may be subtle. Optimizing window level settings and looking for secondary signs such as postobstructive biliary
dilatation can help identify important abnormalities (Fig 15). Other solid liver lesions depicted on breast MR images include focal nodular hyperplasia and hepatic adenoma, both of which also demonstrate a strong predilection for women; hepatic adenoma is associated with the use of oral contraception in women of childbearing age.

**Diffuse Liver Pathology.**—It is important not to overlook diffuse hepatic changes on breast MR images. Hepatosteatosis, for example, is a common form of diffuse liver changes. Although a frequent finding on abdominal MR images, hepatosteatosis is difficult to appreciate on breast MR images unless it is severe. Hepatosteatosis is more common among breast cancer patients (63%-72%) than among healthy women (48%) (27). Although this difference is likely multifactorial, tamoxifen therapy has been reported to exacerbate hepatosteatosis or steatohepatitis, both often associated with abnormal results of a liver function test (28). Of interest, a higher incidence of liver metastases has also been associated with hepatosteatosis among women with metastatic breast cancer (29).

Hepatosteatosis can be diffuse or patchy and appears as increased signal intensity on T1-weighted MR images. In the absence of in-phase and out-of-phase gradient-echo MR images, however, breast MR imaging does not depict hepatosteatosis well. Liver being hyperintense relative to the spleen on T1-weighted MR images is helpful and suggestive of liver fatty infiltration (30).

Occasionally, contour and textural abnormalities of the liver are noted on breast MR images, findings that indicate cirrhosis (Fig 16a, 16b). A small nodular cirrhotic liver may house primary hepatocellular carcinoma and may be associated with ascites caused by portal hypertension. Cirrhosis is nodular regeneration, fibrosis, and architectural distortion resulting from liver cell injury. Whereas cirrhosis is caused by alcohol abuse, viral hepatitis, steatohepatitis, primary biliary cirrhosis, Wilson disease, and hemochromatosis, to name just a few, pseudocirrhosis is a known complication of chemotherapy for diffuse liver metastases from breast cancer and is mostly unique to this clinical setting (Fig 16c). Diffuse breast cancer metastases to the liver after chemotherapy can
Figure 11. Pulmonary findings on breast MR images in three patients. (a, b) Peripheral area of abnormal signal intensity in the right lung in a 42-year-old woman with lupus erythematosus. (a) Axial contrast-enhanced T1-weighted MR image shows a peripheral area of abnormal signal intensity (arrows). (b) Axial CT image shows that the area of abnormal signal intensity on a corresponds to CT findings of nonspecific interstitial pneumonia (arrows). (c–e) Pulmonary nodule in a 59-year-old woman with previous breast cancer. (c) Axial contrast-enhanced T1-weighted MR image shows a pulmonary nodule (arrow). (d, e) Axial chest CT images obtained 3 years before image in c (e obtained higher than d) show the corresponding pulmonary nodule (arrow on d), as well as bronchiectasis and additional bilateral nodular opacities, findings consistent with mucoid impaction. (f) Axial contrast-enhanced T1-weighted MR image of a 64-year-old woman with previous breast cancer shows nonenhancing right apical pulmonary fibrosis (arrow) from remote tuberculosis.

result in subcapsular retraction, mimicking the appearance of cirrhosis. Although the pathophysiology is not well understood, pseudocirrhosis is thought to be related to diffuse tumor infiltration of hepatocytes and the chemotoxic effect causing fibrosis. Despite its radiographic similarity to cirrhosis, pseudocirrhosis does not have histologic findings of regenerative nodules and bridging fibrosis, which are defining changes of true cirrhosis. The complications of cirrhosis, such as portal hypertension and ascites, are less common in pseudocirrhosis but do occur (31).

Lymph Nodes

Regional Lymphatic Spread.—Breast cancer with regional lymphatic spread portends a poor prognosis and increases the stage of the disease. The PPV
of nodal findings on breast MR images is 62% (Table 2) (4,5,7,8). Regional lymph nodes are defined as ipsilateral axillary level I, II, and III nodes (level III equates to medial infraclavicular), supraclavicular nodes, and internal mammary nodes (32). Levels I, II, and III axillary nodes are located, respectively, inferior lateral to, posterior to, and superior medial to the pectoralis minor muscle. Beyond level I axillary lymph nodes, mammography and US do not consistently evaluate deeper nodes well. In contrast, breast MR imaging depicts apical axillary nodes and internal mammary nodes to better advantage, given a larger field of view. Adding MR...
Figure 14. Hemangioma on breast MR images in a 52-year-old woman. (a) Axial T2-weighted STIR MR image shows a T2-hyperintense large right hepatic mass (⁎) that was hypointense on T1-weighted images (not shown). (b) Axial contrast-enhanced T1-weighted subtraction MR image shows initial peripheral nodular and progressive centripetal enhancement, findings consistent with a giant hemangioma.

Figure 15. Incidental diffuse liver changes in a 65-year-old woman with recently diagnosed estrogen receptor–positive, progesterone receptor–positive cancer in the right breast depicted at mammography and US, who underwent breast MR imaging to evaluate the extent of disease. (a) Axial contrast-enhanced T1-weighted MR image obtained without window level adjustment shows that the liver is mildly heterogeneous. (b) Axial contrast-enhanced T1-weighted MR image obtained after window level adjustment shows that adjusting the window level optimized the depiction of a hepatic mass (arrows). (c) Axial contrast-enhanced T1-weighted MR image of a different section shows postobstructive intrahepatic biliary dilatation (arrows), a sentinel secondary sign to help identify a mass. (d) Subsequent dedicated axial contrast-enhanced T1-weighted MR image of the liver better showed the mass, and the patient underwent biopsy with US guidance. The results of histopathologic examination disclosed adenocarcinoma, a finding consistent with metastatic disease.

imaging to US has also been shown to reduce the false-negative rate and increase the negative predictive value (98%) in the evaluation of axillary nodes (33). However, the evaluation of supravacuicular lymph nodes is less consistent and is limited by the superior extent of the field of view on breast MR images. The most common site of regional lymph node recurrence is the axilla (51%) (34). Regional nodal recurrence after breast conservation therapy may be salvaged if not associated with simultaneous distant metastases, with a reported 10-year survival rate of 44% (34). Careful evaluation of regional lymph nodes on breast MR images is therefore essential, both at initial TNM (tumor, node, metastasis) staging (Fig 17) and at later surveillance (Fig 18). Abnormal lymph nodes on MR images appear enlarged and heterogeneous, often with an effaced central fatty hilum (Fig 17b).
Figure 16. Incidental diffuse liver changes on breast MR images in two patients. (a, b) Diffuse liver changes in a 57-year-old woman with a history of ductal carcinoma in situ 10 years previously. (a) Axial contrast-enhanced T1-weighted MR image shows that the liver appeared small and heterogeneous in enhancement, and the liver margin was noted to be slightly irregular (arrows) on limited assessment. (b) Axial US static image helps confirm the nodular liver contour in this patient with untreated hepatitis C who has developed cirrhosis. (c) Diffuse liver metastases in a 56-year-old woman after chemotherapy for triple-negative invasive ductal carcinoma. Axial contrast-enhanced T1-weighted MR image shows that the liver appears diffusely nodular with subcapsular retraction, findings consistent with pseudocirrhosis.

The convention of preoperative determination of axillary nodal involvement prompting axillary lymph node dissection was called into question a few years ago by the American College of Surgeons Oncology Group (ACOSOG) Z0011 trial (35), which found no benefit in performing axillary lymph node dissection in women with early-stage T1 or T2 invasive cancers and one or two positive sentinel lymph nodes treated with chemoradiation therapy, as compared with sentinel lymph node dissection (Fig 17). The implications of these results have been debated, and the study’s short follow-up (median, 6.3 years) and small sample size were criticized. Despite this controversy, because axillary lymph node dissection does not routinely include deeper regional lymph nodes (Fig 19), assessment of these nodes on breast MR images is still of value. For example, a Rotter node (interpectoral node classified as level II) is not routinely removed in the dissection of level I and II axillary nodes and thus represents a potential site of lymphatic spread (36). This location should be carefully evaluated on breast MR images for involvement, for disease staging, and for recurrence surveillance. Similarly, MR imaging–detected involvement of internal mammary and supraclavicular lymph nodes alters radiation therapy planning and should be described.

Distant Lymphatic Metastasis.—Breast cancer metastasis to lymph nodes other than the ipsilateral regional lymph nodes is considered distant spread and is classified as M1 disease according to the American Joint Committee on Cancer TNM staging classification (32). Distant nodes include the ipsilateral cervical, mediastinal, and any contralateral lymph nodes, which are involved 27% of the time in the setting of metastatic breast cancer (Table 1) (10) (Fig 18). Distant nodal metastasis indicates a poorer prognosis, compared with regional nodal spread, with a reported median survival of 43 months (15). In particular, mediastinal nodal metastasis is common in advanced breast cancer; mediastinal nodal metastasis has been reported in 71% of women with metastatic breast cancer in the findings from an autopsy series (37) and has a high PPV of 83% for malignancy (4). Assessment of the mediastinum on breast MR images can be challenging, and adenopathy may be obscured by hilar structures or be degraded by respiratory motion; nevertheless, the mediastinum should be consistently included in nodal evaluation (Fig 18).
Figure 17. Staging of a newly diagnosed invasive ductal carcinoma of the right breast with breast MR imaging in a 52-year-old woman. (a) Axial contrast-enhanced T1-weighted MR image shows an invasive ductal carcinoma (arrow) less than 3 cm in diameter in the right breast. (b) Axial contrast-enhanced T1-weighted MR image (different section, obtained higher in the axilla) shows a single enlarged right axillary lymph node (arrow), a finding consistent with nodal metastasis.

Staging Considerations on Breast MR Images

Skin
Breast cancer involvement of the skin increases the stage of the disease and precludes surgical options with favorable cosmetic results, such as nipple-sparing or skin-sparing mastectomy. Focal skin ulceration or a nodule that is found at clinical examination and is substantiated by direct extension of enhancing tumor to the skin on breast MR images (Fig 20), which is confirmed by the results of a skin punch biopsy, constitutes T4 (at least stage IIIB) disease and carries a poor prognosis (32), with a reported median survival of 43 months (15). In contrast, diffuse skin thickening and abnormal enhancement on breast MR images, often with an underlying mass, correlates with peau d’orange at clinical examination (Fig 21) and represents inflammatory breast cancer with diffuse dermal lymphatic plugging by tumor emboli, which is classified as at least stage IIIB disease (32). Focal enhancing dermal lesions on breast MR images most commonly represent incidental benign lesions such as sebaceous or epidermal inclusion cysts. However, in a patient with a prior history of breast cancer, the skin is occasionally the site of metastasis or recurrence of disease and requires careful evaluation on MR images. New or enlarging focal nodular enhancing skin lesions, particularly 1.5–2 years after breast conservation therapy with radiation therapy, are suspicious in the setting of breast cancer or melanoma (Fig 22) (38) and require histologic evaluation. In contrast, benign posttreatment changes in the skin are typically more diffuse and smooth areas of enhancement or thickening (39).

Chest Wall
Breast MR imaging is highly sensitive in detecting posterior tumor extension to the pectoralis and chest wall muscles, which is depicted as abnormal enhancement within the substance of the muscles. Although disease involvement of the pectoralis major or minor muscles does not equate to chest wall invasion and does not alter clinical staging, this observation is important to make on breast MR images, because it offers a clear understanding of the full disease extent and guides surgical planning. A patient with breast cancer involving the pectoralis muscle would undergo a radical mastectomy, removing the breast as well as the pectoralis major and minor muscles (Fig 23). In contrast, chest wall invasion is defined as tumor involvement of the serratus anterior and intercostal muscles, as well as the ribs. Chest wall invasion on breast MR images indicates stage IIIB disease, regardless of the
primary tumor size (32) (Fig 24), and usually warrants neoadjuvant chemotherapy because a negative surgical margin could not be obtained in this setting.

Other Clinically Important Considerations on Breast MR Images

Cardiovascular Structures

Heart.—The heart is consistently imaged on contrast-enhanced breast MR images. Cardiac conditions incidentally noted on breast MR images should be described, particularly in a patient who will be undergoing chemotherapy for breast cancer, which can be highly cardiotoxic (eg, doxorubicin therapy). The cardiac size is easily assessed on breast MR images by using a cardiothoracic ratio derived from the width of the heart divided by the width of the chest span. As on a chest radiograph or CT image, a cardiothoracic ratio greater than 0.5 is suggestive of cardiomegaly (Fig 25a) (40,41). Similarly, disproportionate enlargement of one or two cardiac chambers is suggestive of cardiomegaly or cardiomyopathy (Fig 25a). Secondary signs of a cardiac abnormality on breast MR images, such as valve replacement (Fig 25a) or a prior sternotomy (Fig 25b), should direct...
attention to the heart. Rarely, the orientation of the heart is abnormal. The cardiac apex pointing to the right constitutes dextrocardia, a condition found in 0.2% of the population (42). Approximately 27% of those with dextrocardia have associated situs inversus, with a complete mirror-image reversal of the normal anatomic configuration (Fig 26b) (43).

**Great Vessels.**—The thoracic aorta and great vessels are included in the field of view on breast MR images. Although acute or subacute abnormalities such as aortic dissection or aneurysms are rarely depicted on breast MR images, the entire extent of the imaged thoracic aorta should be carefully assessed, particularly on the sagittal projection, where this vessel is often imaged to the greatest extent. Developmental anomalies involving the great vessels arising from the aortic arch are occasionally seen on breast MR images, some of which may be symptomatic and previously undiagnosed (Fig 27). In particular, an aberrant right subclavian artery occurs in approximately 1% of the population, with the right subclavian artery arising as the last branch of the aortic arch and taking a retroesophageal course 80% of the time, which causes the so-called dysphagia lusoria (44) (Fig 27). In comparison, a right aortic arch is an even less-common congenital anomaly that occurs in less than 0.1% of the population (Fig 26a). Most patients with right aortic arch, however, are asymptomatic. Right aortic arch with an aberrant left subclavian artery with a retroesophageal course may be symptomatic, particularly when a vascular ring is formed with the ligamentum arteriosum. This combination is rarely associated with congenital cardiac conditions (44). In contrast, a right aortic arch with mirror-image branching (in order of left innominate artery, right carotid artery, and right subclavian arteries) is almost always associated with congenital heart disease and manifests early in life. Consistently inspecting the vascular structures in their course and caliber will help identify rare but clinically important findings on breast MR images.
Figure 24. Chest wall involvement on a breast MR image in a 48-year-old woman with cancer of the left breast. Sagittal contrast-enhanced T1-weighted MR image shows abnormal enhancement (arrow) within the left serratus anterior and intercostal muscles, a finding consistent with chest wall invasion.

Figure 25. Incidental cardiac findings on breast MR images in two patients. (a) Axial contrast-enhanced T1-weighted MR image of a 72-year-old woman with newly diagnosed breast cancer shows severe cardiomegaly with marked right atrial enlargement (short solid arrows), a sequela of previous rheumatic disease. Note susceptibility artifacts (dashed arrow) caused by a prosthetic mitral valve. Incidentally, a large hiatal hernia (long solid arrows) is depicted in the retrocardiac location. (b) Axial contrast-enhanced T1-weighted MR image of a 68-year-old woman shows susceptibility artifacts (arrow) caused by the wire from a previous sternotomy, a finding indicating a history of cardiac pathologic conditions.

Figure 26. Incidental cardiac findings on breast MR images in two patients. (a) Axial screening contrast-enhanced T1-weighted MR image of a 37-year-old woman shows an incidental finding of a right aortic arch (arrows). (b) Axial contrast-enhanced T1-weighted fat-saturated MR image of a 46-year-old woman shows incidental findings of dextrocardia (white arrow) and a centralized descending aorta (black arrow), as well as a left-sided liver and right-sided stomach and spleen, findings consistent with situs inversus that were also depicted at CT (CT images not shown).
Gastrointestinal Structures

Common Benign Gastrointestinal Findings.—The proximal gastrointestinal tract depicted on breast MR images includes the esophagus, the gastroesophageal junction, and the stomach. Although gastrointestinal abnormalities only account for approximately 3% of the extramammary findings on breast MR images (2), these gastrointestinal findings are often symptomatic and are therefore clinically important. Hiatal hernia is the most common incidental gastrointestinal finding on breast MR images, depicted as superior displacement of the gastroesophageal junction and intrathoracic herniation of the stomach through the esophageal hiatus (Fig 5a). The normal collapsed esophagus is not well assessed at cross-sectional imaging unless the structure is distended with air, contrast material, or fluid. Occasionally, a distended thickened esophagus may indicate distal obstruction or narrowing and may bring attention to the area of interest (Fig 28). The gastroesophageal junction is posterior in location on breast MR images but should be included in the checklist of structures to evaluate.

Unusual Malignant Involvement of the Gastrointestinal Tract.—The gastrointestinal tract is an unusual location for breast cancer metastasis but is a frequent site of spread for invasive lobular carcinoma of the breast and hence warrants careful evaluation on breast MR images. In addition to the common sites of metastasis to the liver, lungs, bones, and lymph nodes, invasive lobular carcinoma has a propensity to metastasize to locations unusual for invasive ductal carcinoma, including the gastrointestinal tract, peritoneum, retroperitoneum, adrenal glands, gynecologic organs, and leptomeninges. In the results of a study of 2605 cases of metastatic breast cancer, investigators demonstrated that invasive lobular carcinoma metastasized significantly more frequently \((P < .05)\) to these sites, compared with invasive ductal carcinoma (45). The gastrointestinal tract, peritoneum, and adrenal glands are often depicted on breast MR images and should be carefully evaluated (Fig 29).

Systematic Approach to Evaluating Extramammary Structures on Breast MR Images

The Challenge
The inherent challenge is that breast MR imaging is not tailored to assess structures outside the breast. The depicted extramammary lesions therefore may not be well characterized. MR imaging protocols vary for different target organ systems, in the types of coils used, the sequences...
acquired, and the timing of contrast-enhanced imaging. Dedicated breast coils are placed close to the breasts to maximize signal return and therefore receive weaker signals from adjacent structures. For that exact reason, careful assessment of the extramammary structures is necessary. Contrast bolus timing for breast MR imaging is tailored to highlight early arterial enhancement of breast cancer and may not depict late-enhancing lesions in the liver, lungs, or bones well. Thus, in the cases in which an extramammary lesion is incompletely imaged or evaluated on breast MR images, a dedicated organ-specific study would be warranted. That being said, using the available sequences for breast MR imaging, in combination with comparisons with prior images, is often enough to reach a benign diagnosis in some cases.

Systematic Approach
To best evaluate extramammary structures on breast MR images, technical parameters must be optimized, and the radiologist must have a systematic approach. A well-performed breast MR imaging examination will have a high signal-to-noise ratio and minimized motion degradation. Actively adjusting the window level while evaluating structures outside the breast helps to increase diagnostic sensitivity (Fig 15a, 15b). Evaluating all projections of images allows multiplanar correlation. In addition, the radiologist should beware of findings that are partially concealed by saturation bands (Fig 30). The American College of Radiology Breast MR Imaging Accreditation Program requires the following sequences: a three-plane localizer, T2-weighted sequence, and T1-weighted dynamic contrast-enhanced sequences (including a nonenhanced and an early and delayed contrast-enhanced series) (46). The field of view is the largest on scout images, which, although of limited resolution, should be evaluated to exclude partially imaged abnormalities at the edge of the field of view. It is possible that a finding may only be depicted on the scout image and not with any other sequences. Fluid-sensitive T2-weighted sequences for breast MR imaging are helpful for the characterization of focal findings. The early-phase contrast-enhanced sequence occurs between 1 and 2 minutes after contrast material injection, to capture the peak enhancement of invasive cancers. The mid to delayed contrast-enhanced sequence occurs between 4 and 15 minutes after contrast material injection, to capture the late arterial and venous phases of enhancement.
enhanced sequences best overlap with the portovenous phase at CT and MR body imaging, allowing the best visceral evaluation. Ultimately, as with any other examination, a consistent approach to evaluating extramammary structures on breast MR images consisting of the “same way, every time” (Fig 31) minimizes the chance that a finding may be overlooked. Furthermore, a systematic assessment of particularly the high-prevalence and high-PPV organ systems for metastasis in the bones, lungs, liver, and nodes helps ensure that the most important findings are consistently identified.

**Conclusion**
Extramammary findings on breast MR images are most likely to be pertinent for those patients with a new or prior diagnosis of breast cancer, a group that accounts for more than half of the patients undergoing breast MR imaging. Understanding the frequency and distribution of common sites of breast cancer metastasis in the bones, lungs, liver, and lymph nodes is helpful in delineating important abnormalities in high-yield (high-PPV) organ systems on breast MR images. The emphasis on a systematic diagnostic approach allows for consistent identification of disease not only at the common sites of metastasis, but also at less-common metastatic sites in the gastrointestinal tract, peritoneum, and adrenal glands, and allows the capture of benign but clinically important findings. Ultimately, extramammary findings on breast MR images should be interpreted in the clinical context of each case, and the workup of these findings should be dictated by the implications for disease staging, treatment, and potential clinical outcomes.

**Acknowledgments.**—The authors wish to thank Luke Mueller, MD, New York University, New York, NY; Vanessa Wear, MD, Advocate Illinois Masonic Medical Center, Chicago, Ill; and Amy Melsaether, MD, New York University, New York, NY, for contributing illustrative cases to this work.

**References**
Figure 30. Findings concealed by a saturation band on breast MR images in a 66-year-old woman of Ashkenazi descent who had a family history of breast cancer, as well as a history of lobular carcinoma in situ in 2008. (a) Axial contrast-enhanced T1-weighted MR image shows no obvious abnormality. Assessment was limited by a large saturation band posteriorly. (b) Axial contrast-enhanced T1-weighted MR image obtained after optimizing the window level shows an exophytic enhancing right renal mass (arrows), which later proved to be a renal cell carcinoma, for which the patient underwent right nephrectomy.


