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Using T2-Weighted Sequences to More Accurately Characterize Breast Masses Seen on MRI

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MRI is the most sensitive method for the detection of breast cancer. Most commonly used as a screening tool in high-risk patients, MRI is also of value to further evaluate an abnormality seen on mammography or ultrasound, show the extent of disease in a known breast cancer, and assess response to neoadjuvant chemotherapy. The reported specificity of breast MRI is variable, although magnets of higher field strength (1.5 and 3 T), improvements in imaging techniques (parallel imaging), and better breast coils (7–16 channels) have enhanced spatial and temporal resolution and speed of acquisition, resulting in improved ability to differentiate benign from malignant masses.

Interpreting T2-Weighted MRI

The differential diagnosis of breast masses using MRI is based on the morphology of the lesion, perfusion kinetics, and comparison of signal intensity on T1- and T2-weighted and unenhanced and contrast-enhanced images. Careful analysis of T2-weighted images can reduce the false-positive rates and permit rare well-circumscribed breast carcinomas to be distinguished from common benign breast masses. Most breast MRI protocols include a T2-weighted unenhanced sequence, with or without fat suppression. T2-weighted images with fat suppression allow easier visibility of fluid intensity but at the expense of spatial resolution. T2-weighted images without fat suppression provide better depiction of the normal tissue architecture and lesion morphology.

In contrast to T1-weighted sequences, which highlight anatomic detail and contrast enhancement, fluid-sensitive T2-weighted sequences depict edema, hemorrhage, mucus, or cystic fluid. In breast tissue, edema can result from trauma, postirradiation changes, and venous or lymphatic congestion. Hemorrhage and necrosis can occur after trauma or surgery but are also rarely seen with central infarction in large high-grade breast tumors. Mucus secreted by apocrine or epithelial cells of the breast can accumulate in benign (myxomatous fibroadenoma) or malignant (mucinous adenocarcinoma) masses. In the differential diagnosis of breast masses on MRI, most masses that have high signal intensity on T2-weighted images are benign. However, several rare malignancies may also appear bright on T2-weighted images, so it is important for radiologists to be familiar with the appearances and characteristics of T2-bright masses of the breast (Table 1).

Benign Masses

Cysts

Breast cysts are common benign lesions that are formed by dilation and unfolding of ducts. They consist of a thin epithelial lining, which secretes fluid that accumulates in the lumen of the cyst. Clinically, a cyst is felt as a firm, round, and movable lump. On imaging, breast cysts have smooth well-defined borders and are most often round, although they can be oval or lobulated. In a simple cyst, the cystic fluid is serous and thus appears uniformly hyperintense on T2-weighted MR images (Fig. 1A). Complicated cysts can have hyper, hypo-, or heterogeneous signal intensity on T2-weighted images because of their proteinaceous or sanguineous fluid contents (Fig. 2). Layering of fluid contents is a benign finding. Breast cysts usually are hypointense on T1-weighted images and do not show contrast enhancement. Important exceptions to this general rule are inflammatory cysts (Figs. 1B and 2C), which may show rim enhancement, known as the "solar eclipse" sign. When this occurs, it is important to make certain that the rim enhancement is thin and uniform and has no nodularity.

Nodules may occasionally be seen within a breast cyst. They appear hypointense on T2-weighted sequences but usually are hyperin-

tense and show contrast enhancement on T1-weighted images. A single nodule generally indicates an intracystic papilloma, but the presence of multiple intramural nodules is concerning for malignant intracystic papillary carcinoma or necrotic malignancy.

Apocrine Metaplasia

Apocrine metaplasia arising from a profusion of lobular cells in the terminal ductal-lobular units of the breast is associated with fibrocystic changes and may appear as a lesion on MRI. These apocrine cells secrete fluid that accumulates in dilated ducts and cystic spaces, appearing bright on T2-weighted images. Although a nonproliferative, benign process, apocrine metaplasia can have suspicious features on imaging. The masses related to apocrine metaplasia tend to have a lobular shape and microlobular or indistinct margins that depend on the complexity of the papillary change that often develops. There may be heterogeneous or no enhancement, and the level of high signal intensity on T2-weighted images varies. An area of mild enhancement with a microcystic appearance and high signal intensity on T2-weighted images and no other suspicious features (architectural distortion, skin thickening, nipple retraction, or lymphadenopathy) is typical of apocrine metaplasia, which can usually be safely followed-up with imaging (Fig. 3).

Myxomatous Fibroadenoma

Fibroadenomas are a common clinical and radiopathologic finding in breast tissue. The lesion is usually a discrete, round or lobulated, freely moving nodule. It is composed of glandular epithelial-lined spaces surrounded by fibrous stroma that can be either myxoid or sclerotic. Myxoid fibroadenomas have edema and mucus accumulation in the extracellular stroma and usually represent masses at an earlier stage of development. Over time, hyalinization and calcification of the stroma can result in the sclerotic form. On MRI, fibroadenomas appear as focal round, oval, or lobulated masses with smooth margins. They typically show slow progressive enhancement. On T2-weighted images, myxoid fibroadenomas have very high signal intensity (correlating with the fluid-dense mucinous stroma) and tend to show slow mild enhancement (Fig. 4). Sclerotic fibroadenomas have little to no enhancement and very low signal intensity on T2-weighted images (Fig. 5). One key to diagnosing fibroadenomas on MRI is the presence of dark internal septations, which correspond to bands of dense connective tissue running through the lesion. When present, they are pathognomonic for fibroadenoma and no further workup is required.

Fat Necrosis

Fat necrosis is an inflammatory lesion that develops after trauma or surgery. It may present clinically as a painless palpable mass or be discovered incidentally on breast imaging. The area is composed of peripheral fibrosis surrounding a necrotic core, and the degree of fibrosis and necrosis determines the appearance on MRI. Fat undergoes liquefactive necrosis, which appears bright on T2-weighted images. Necrotic areas generally have a globular appearance and intermediate signal intensity that is higher than surrounding fat but not as bright as a simple cyst. Therefore, non–fat-suppressed sequences are best for distinguishing fat necrosis from possible malignant masses, such as necrotic cancer. At times, areas of necrosis wall off to form oil cysts. Because inflammatory cells and hemorrhage may be present, areas of fat necrosis can show fast enhancement. Skin thickening and retraction may occur. The presence of central fat signal intensity (Figs. 6 and 7) is the key to differentiating fat necrosis from tumor recurrence because breast cancers usually do not contain macroscopic central fat. Correlation with mammography and clinical history can aid in diagnosis when the MRI findings are unclear.

Lymph Nodes

Lymph nodes are commonly seen on breast imaging, usually in the axilla or upper-outer quadrant of the breast. These aggregates of lymphoid tissue are surrounded by a thin capsule and contain a central fatty region. On imaging,

TABLE 1: Appearance and Characteristics of Masses

Masses	Morphology	Enhancement Pattern on T1-Weighted Images	Abnormality
Benign T2-bright			
Apocrine metaplasia	Lobular with indistinct or microlobular margins	Mild, heterogeneous, or none; variable kinetics	Dilated ducts and microcysts with micropapillary change and secretions
Cyst	Round or oval with smooth margins	Usually none; may be heterogeneous (complicated cyst) or smooth rim (inflammatory cyst); kinetics usually progressive; type 1 at the rim	Thin epithelial lining with serous, serosanguinous, or proteinaceous fluid
Myxoid fibroadenoma	Round or oval smooth margins, rarely irregular	Dark internal septation, homogenous or rarely rim; kinetics usually progressive; type 1	Fibrous stroma with extracellular edema or mucus surrounding ductal or cystic spaces with epithelial hyperplasia
Fat necrosis	Round or irregular with smooth or irregular margins	Central; variable kinetics	Foamy histiocytes with peripheral fibrosis and necrotic center
Lymph node	Oval or reniform with smooth or lobulated margins, hypointense central hilum	Central or none; kinetics usually washout, type 3	Encapsulated mixed lymphoid population with a fatty hilum containing blood and lymph vessels
Malignant T2-bright			
Mucinous carcinoma	Round, oval, or lobular with smooth margins	Rim; variable kinetics	Well-differentiated tumor cells in small clusters surrounded by mucus pool
Necrotic cancer (medullary or metaplastic)	Variable appearance	Homogenous or rim; variable kinetics; may see washout type 3 along the periphery and solid components	Poorly differentiated or metaplastic cells with central necrosis and cystic degeneration

lymph nodes appear as small oval masses with well-circumscribed smooth or sometimes lobulated margins; in cross-section, they may be donut- or C-shaped. On T2-weighted images, peripheral lymph nodes have a reniform shape and appear as homogeneous intermediate-signal-intensity nodules with a high T2-signal-intensity central hilum that is similar in signal intensity to fat. T1-weighted images often show lymph nodes as low-signal-intensity nodules with rapid contrast enhancement and washout kinetics because of their high vascularity (Fig. 8). On MRI, the presence of an eccentrically located hilar region with a uniform thin cortex indicates a benign lymph node, which may be associated with a feeding vessel.

In patients with breast cancer, MRI is not the modality of choice for axillary staging because benign and malignant lymph nodes cannot be reliably differentiated. However, lymph nodes that appear round, are larger than 10 mm, or have an absent fatty hilum are suspicious for metastasis. Because lymphoid tissue may be completely replaced by carcinoma cells, metastatic lymph nodes may lose their reniform shape and have low signal intensity on T2-weighted images.

Malignant Masses

Most invasive carcinomas of the breast have a suspicious appearance on MRI, with spiculated or irregular borders and rapid internally heterogeneous or rim enhancement. On T2-weighted images, the rule of thumb is that most cancers are hypointense relative to fibroglandular tissue because of their dense cellularity. However, several rare types of breast cancer—including mucinous, medullary, papillary, and metaplastic carcinomas—can have high signal intensity on T2-weighted sequences. These rare cancers may occasionally have smooth well-circumscribed borders mimicking benign masses. Careful attention to the T2-weighted images can often help in differentiating benign from malignant breast masses.

Mucinous Carcinoma

Mucinous carcinoma is a well-differentiated adenocarcinoma that usually occurs in women older than 65 years and tends to progress slowly. The malignant cells in mucinous carcinoma secrete large amounts of extracellular mucin. There are two forms of mucinous cancer. Pure mucinous forms consist of small islands of cells that are surrounded by mucus and have no significant solid component, whereas mixed forms have both mucinous and solid components. These cancers have heterogeneous or rim enhancement related to the distribution of the neoplastic cells, often having benign-appearing kinetics with gradual persistent enhancement. Mucin has a long T2 relaxation time, which gives these tumors a bright cystlike appearance on T2-weighted images (Fig. 9). Pure mucinous cancers tend to have a lobulated oval or round shape with smooth or irregular margins. In mixed forms, the increasing cellularity leads to more irregular borders and more heterogeneous signal intensity. An important diagnostic clue in differentiating mucinous cancer from myxomatous fibroadenomas, cysts, or abscesses is the presence of a thickened, enhancing, or irregular rim and high signal intensity on T2-weighted images.

Necrotic Cancer

Central necrosis occurs when a tumor outgrows its blood supply. This can occur in several types of breast cancer, such as large high-grade intraductal carcinomas, medullary carcinoma, or metaplastic carcinoma. The cellular breakdown within the infarcted tissue leads to the accumulation of fluid and debris, causing high signal intensity on T2-weighted images. Inflammation associated with necrosis often leads to stromal edema within the tumor, which contributes to the high T2 signal intensity. The remaining viable tumor surrounding an area of necrosis typically has features suspicious for malignancy, such as strong rapid enhancement, nodular or irregular configuration, and hypointense appearance on T2-weighted images (Fig. 10). Non–fat-suppressed sequences are best for distinguishing fat necrosis from possible malignant masses, such as necrotic cancer. The presence of central fat signal intensity is the key to differentiating fat necrosis from tumor recurrence.

Summary

T2-weighted images are a valuable component of the MRI evaluation of breast masses. Edema, hemorrhage, mucus, and cystic fluid within a lesion are clearly depicted on T2-weighted sequences. In general, masses that have high signal intensity on T2-weighted images are benign; however, breast imagers must be aware of such important exceptions as mucinous carcinoma and necrotic tumors.

Suggested Reading

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(Figures follow on next page)

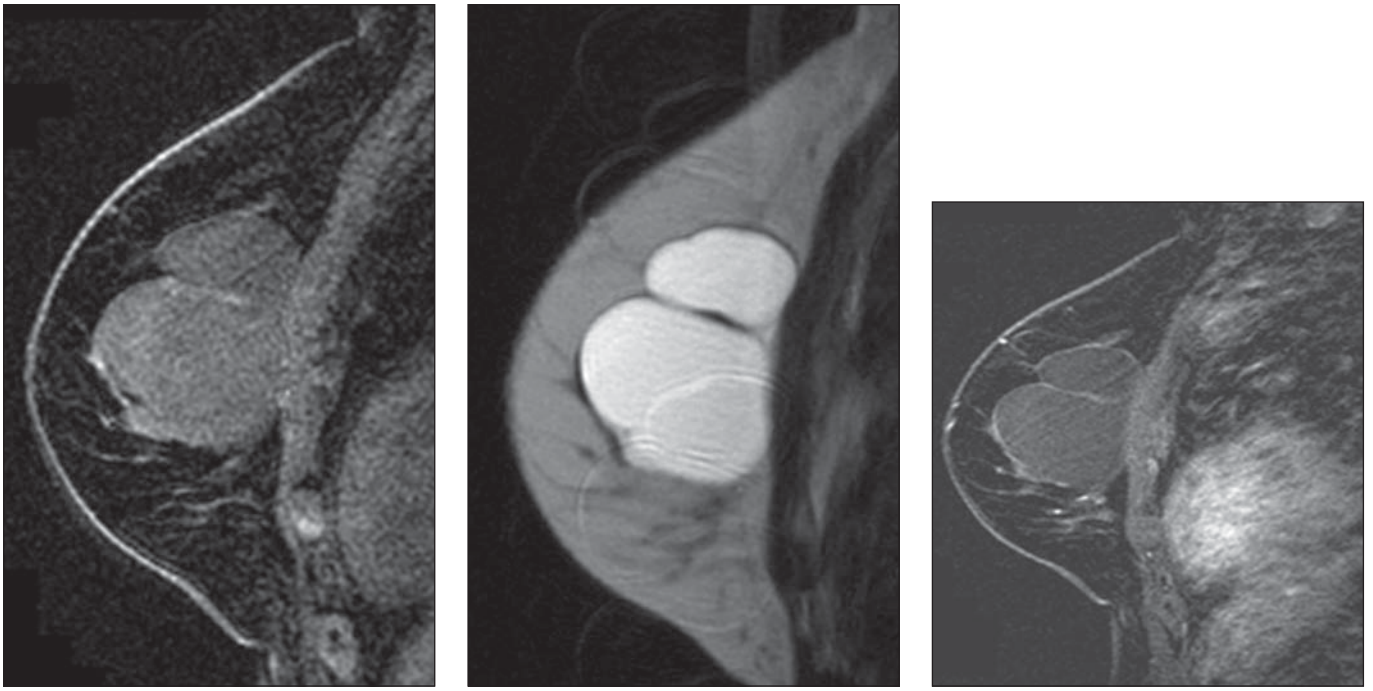

Fig. 1—Simple cyst in 42-year-old woman who presented for high-risk screening breast MRI.
A and **B,** T1-weighted (**A**) and T2-weighted (**B**) MR images show uniformly hyperintense signal in two adjacent simple cysts.
C, Contrast-enhanced subtraction image shows thin rim of smooth enhancement, indicative of inflammatory reaction.

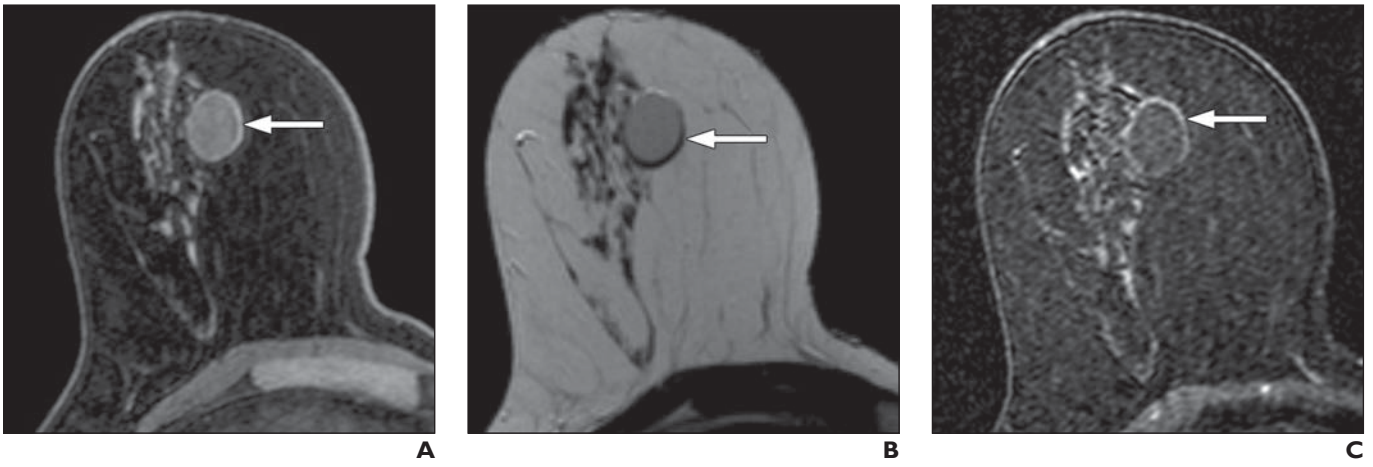

Fig. 2—Complicated cysts in 48-year-old woman with history of premenopausal breast cancer who presented for screening MRI.
A–C, Hyperintense circumscribed mass (*arrow*) is seen on T1-weighted (**A**) and T2-weighted (**B**) images because of proteinaceous or sanguineous contents of cystic fluid. Note thin rim of enhancement on contrast-enhanced image (**C**).

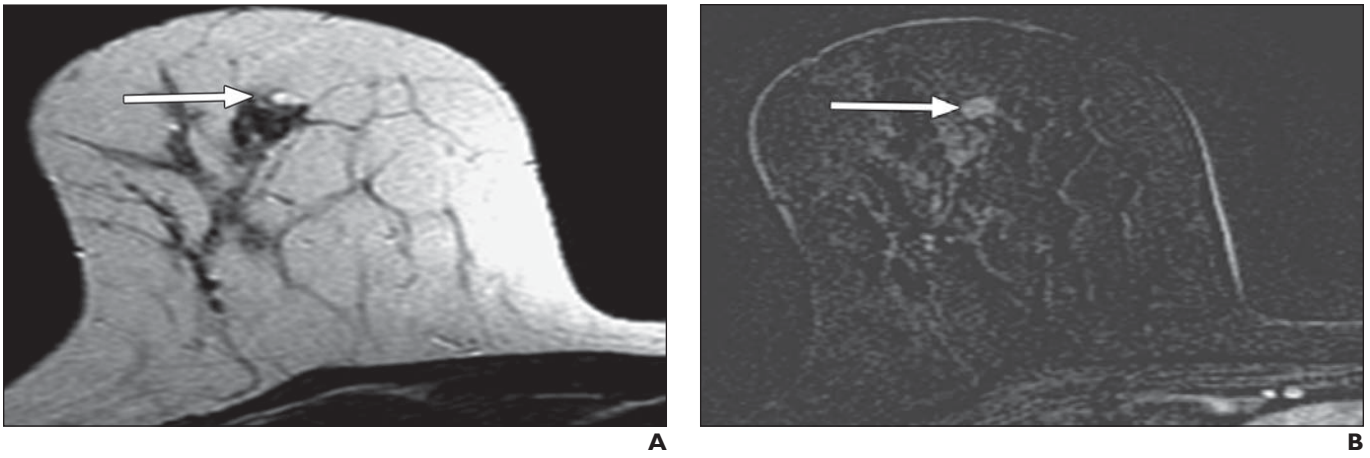

Fig. 3—Apocrine metaplasia in 50-year-old woman who presented for high-risk screening MRI.
A and **B,** T2-weighted image (**A**) shows well-circumscribed 5-mm mass with high signal intensity (*arrow*, **A**) and enhancement (*arrow*, **B**) on contrast-enhanced image (**B**), without other suspicious features.

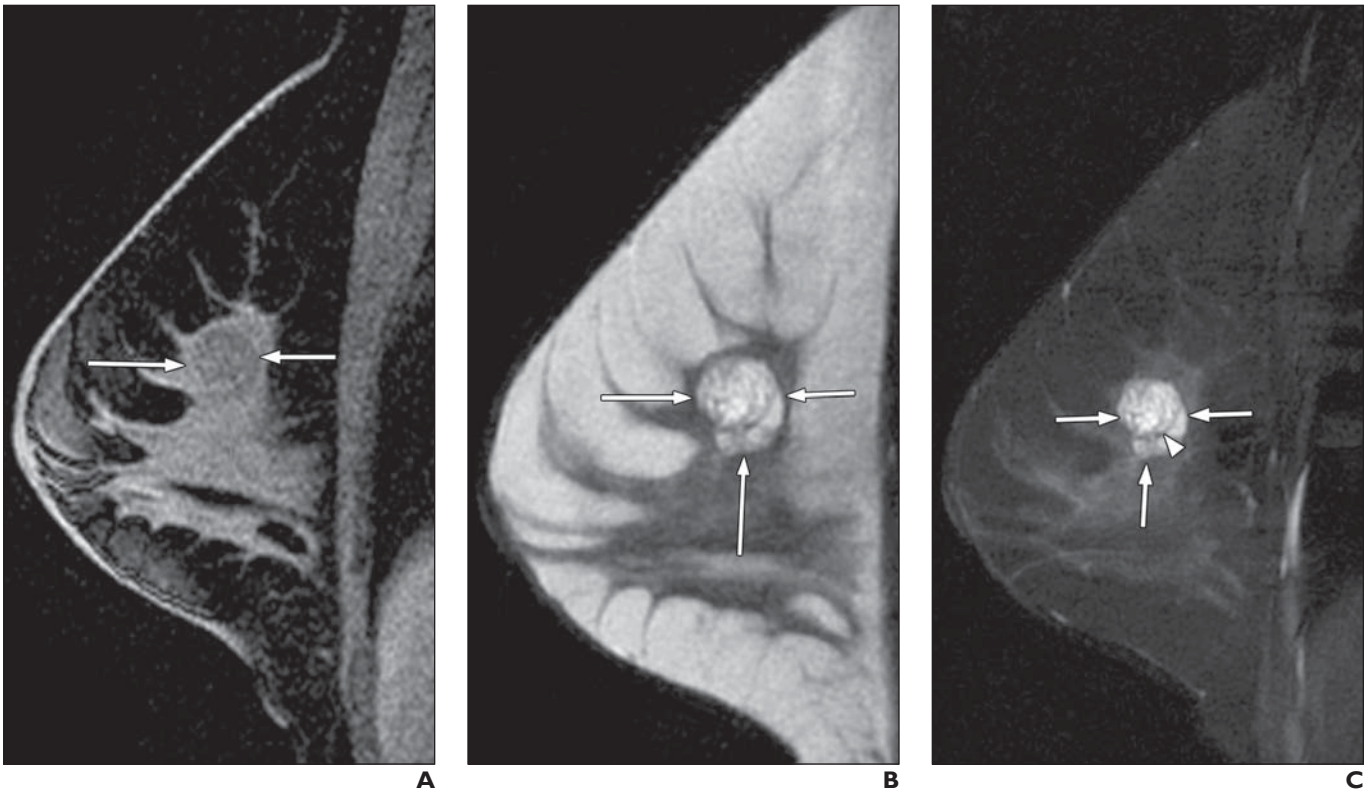

Fig. 4—Myxomatous fibroadenoma in 54-year-old woman with history of breast cancer who had focal round mass with smooth margins detected on screening MRI.
A, T2-weighted image shows round mass (*arrows*) with typical high signal intensity, which correlates with fluid-dense mucinous stroma.
B and **C,** Unenhanced (**B**) and contrast-enhanced (**C**) images show homogeneous enhancement (*arrows*) and nonenhancing dark internal septations (*arrowhead*).

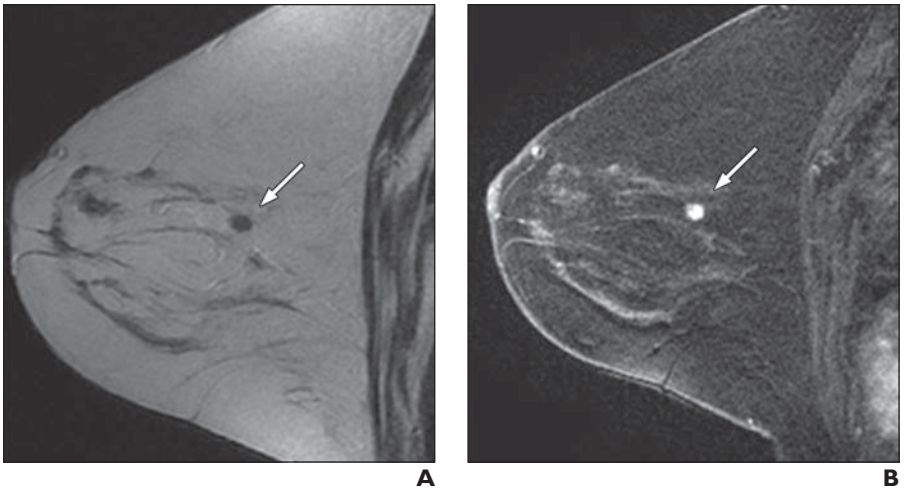

Fig. 5—Sclerotic fibroadenoma in 59-year-old woman who had focal round mass (*arrow*) with smooth margins detected on screening MRI.
A and **B,** T2-weighted image (**A**) shows low signal intensity, and contrast-enhanced image (**B**) shows homogeneous enhancement.

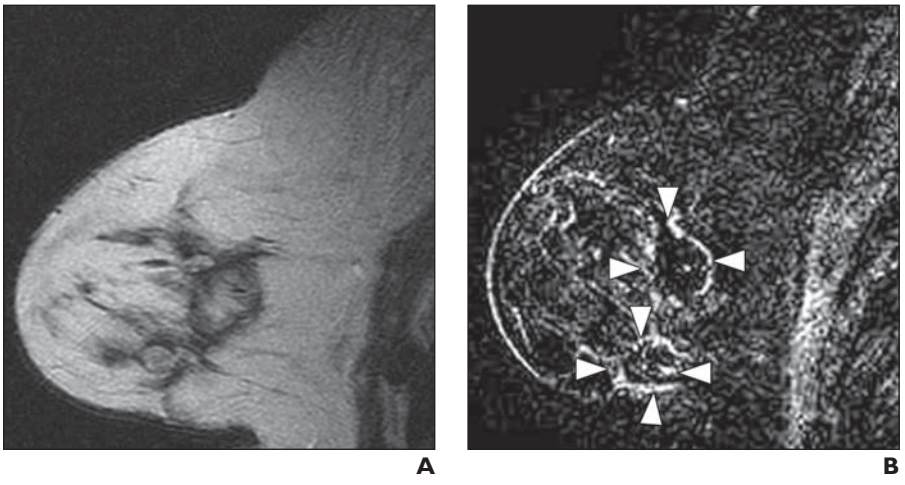

Fig. 6—Fat necrosis in 63-year-old woman with history of reduction surgeries and lobular carcinoma in situ who presented for high-risk screening MRI.
A, T2-weighted image shows lobulated mass with high signal intensity, isointense with surrounding fatty tissue.
B, Loss of signal intensity on fat-suppressed image confirms presence of central fat (*arrowheads*).

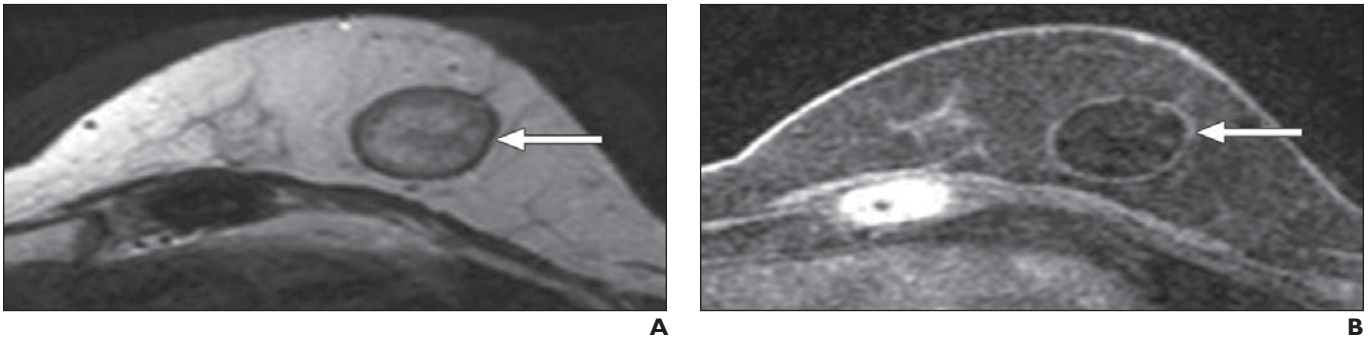

Fig. 7—Oil cyst associated with fat necrosis in 56-year-old woman with history of breast cancer and fat transfer in both breasts.
A and **B,** MR images show well-circumscribed round mass with central high signal intensity (*arrow*) on T2-weighted image (**A**) and loss of signal intensity on fat-suppressed contrast-enhanced image (**B**), with thin rim of smooth enhancement.

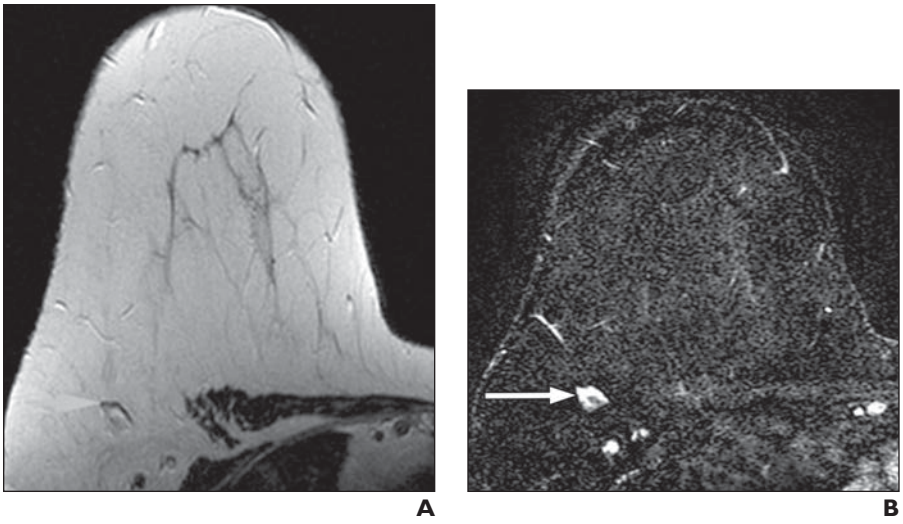

Fig. 8—Normal axillary lymph nodes in 54-year-old woman with recent diagnosis of contralateral breast cancer.
A, T2-weighted MR image shows reniform mass with central high signal intensity of fatty hilum and peripheral dark signal intensity.
B, Contrast-enhanced fat-suppressed image shows rapid peripheral enhancement (*arrow*), and central fatty hilum shows loss of signal intensity.

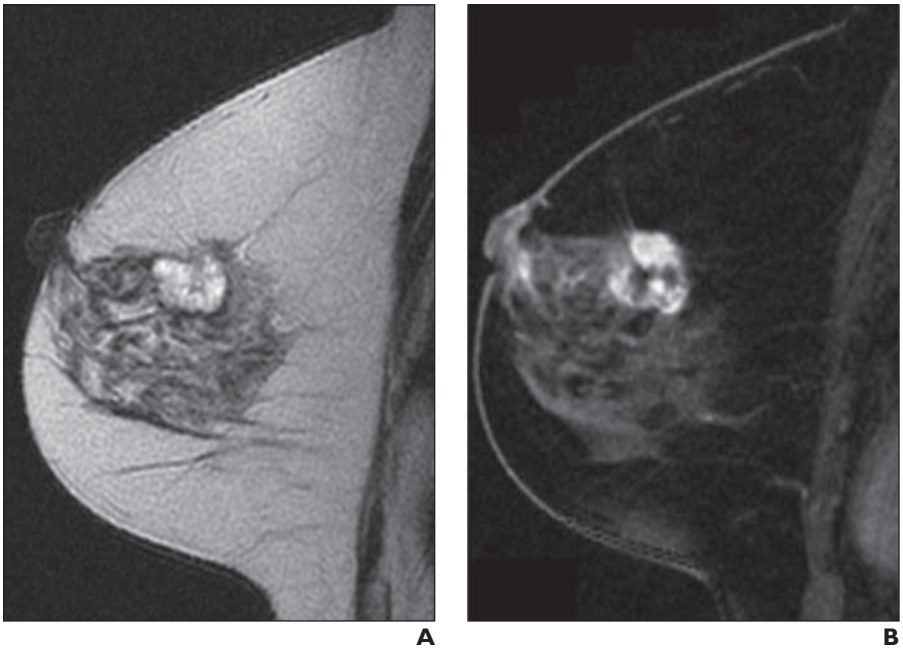

Fig. 9—Mucinous cancer in 65-year-old woman who presented with palpable lump.
A T2-weighted MR image shows irregular mass with high signal intensity due to presence of mucin.
B, Contrast-enhanced MR image shows inhomogeneous enhancement of mass.

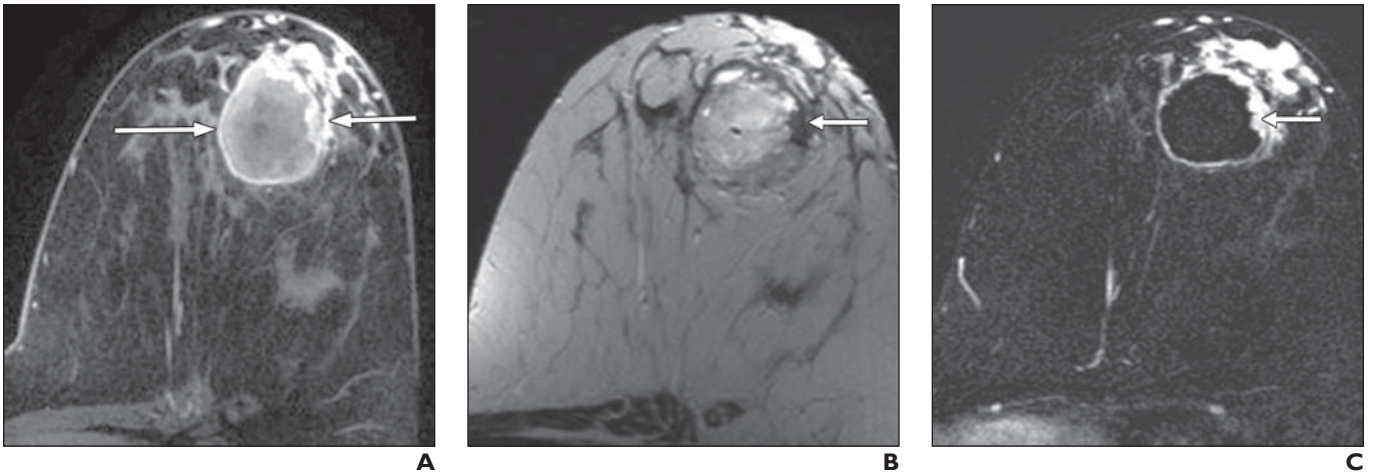

Fig. 10—Necrotic intraductal carcinoma in 40-year-old woman with recent diagnosis of breast cancer.
A–C, T1-weighted (**A**) and T2-weighted (**B**) images show complex cystic mass (*arrows*, **A**) with heterogeneous intensity. Peripheral dark nodules on T2-weighted image (*arrow*, **B**) show intense nodular enhancement on contrast-enhanced image (**C**). Note central T2-bright necrotic component does not show any enhancement.