6
Breast Magnetic Resonance Imaging Lexicon

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As contrast enhanced breast magnetic resonance imaging (MRI) becomes more ubiquitous, standardization of terminology has become necessary. To this end, the American College of Radiology (ACR) has sponsored the development of a lexicon that is finalized and is now available. This chapter attempts to illustrate some of the terms that are used in this lexicon. It should be emphasized that this chapter does not replace the ACR BI-RADS™ (Breast Imaging Reporting and Data System) MRI Lexicon. The purpose of this chapter is to familiarize the reader with concepts and terminology in breast MRI interpretation that may be useful.[1–4]

The need for a lexicon becomes apparent when interpreting contrast-enhanced breast MRI as there are many different types of enhancement seen. Because enhancement alone is not sufficient for the diagnosis of malignancy, a method to describe findings is essential. Additionally, each lesion contains information about morphological characteristics as well as information about the dynamics of the contrast enhancement. By analyzing both the morphology and kinetic behavior of a lesion, the specificity of breast MRI is improved. A preliminary lexicon describing both architectural features and dynamic parameters is presented. This chapter focuses on the morphology of both benign and malignant breast lesions seen on breast MRI.

1. Standardization of Terminology

During the past decade, as multimodality breast imaging, including MRI, has become incorporated into the clinical evaluation of the breast, it has become apparent that standardization of terminology is important, particularly across modalities. As with mammography, concise, clear, easily understood language is needed when describing a lesion seen on breast MRI, so that the description can be understood without the benefit of looking at the actual image. The need for a standardized lexicon for analysis of findings identified on breast MRI is twofold: to concisely describe the findings to facilitate communication between radiologists and referring physicians and to allow analysis of outcomes across institutions to validat management recommendations.

Over the past several years, an international working group consisting of breast MRI experts from around the world has been supported by the ACR to arrive at a consensus lexicon that would describe the findings that are seen on breast MRI.[1–3] One of the goals of the group was to arrive at a consensus regarding architectural and kinetic features that are seen on contrast-enhanced breast MRI. Terms that were proposed by the group are listed in Table 6.1.

The group has expressly tried to incorporate familiar language such as that used in BI-RADS for mammography.[5] When a BI-RADS descriptor could be used, it was applied and new descriptors were developed for findings unique to MRI. By virtue that breast MRI uses contrast and mammography does not, terms to describe the kinetic uptake of contrast by the lesion are unique to breast MRI. Similarly, aspects of morphologic analysis, such as pattern of enhancement, are unique to the breast magnetic resonance examination. The shape and margin analysis is similar to BI-RADS™.

Lesion interpretation in breast MRI relies entirely on lesion enhancement. When analyzing a breast MRI examination, the first step is to establish that the patient received an adequate dose of intravenous contrast. While there are several sophisticated methods that can assess the presence of contrast, the simplest form of confirmation that contrast was received is that vessels in the breast are identified as enhancing structures and contrast is seen in the heart.

Solely identifying an enhancing area on breast MRI as suspicious will not optimize the specificity of breast MRI

Adapted from Morris EA. Illustrated breast MR lexicon. *Semin Roentgenol.* 2001;36:238–249, with permission from Elsevier.

Table 6.1. Breast MRI Terms Proposed by the International Working Group of the American College of Radiology

- Focus/foci
- Mass margin
  - Smooth
  - Irregular
  - Spiculated
- Mass shape
  - Round
  - Oval
  - Lobular
  - Irregular
- Mass enhancement
  - Homogeneous
  - Heterogeneous
  - Rim
  - Dark internal septation
  - Enhancing internal septations
  - Central enhancement
- NonMass enhancement
  - Focal
  - Linear
  - Ductal
  - Segmental
  - Regional
  - Multiple regions
  - Diffuse
- NonMass enhancement descriptors for all other types
  - Homogeneous
  - Heterogeneous
  - Stippled/punctate
  - Clumped
  - Reticular/dendritic
- Symmetric versus asymmetric for bilateral studies
- Other findings
  - Nipple retraction
  - Nipple invasion
  - Precontrast high duct signal
  - Focal skin thickening
  - Diffuse skin thickening
  - Skin invasion
  - Edema
  - Lymphadenopathy
  - Pectoralis muscle invasion
  - Chest wall invasion
  - Hematoma/blood
  - Abnormal signal void
  - Cysts

and will result in too many false-positive biopsy results. For the best analysis, all features of the lesion should be analyzed, including kinetics as well as morphology of enhancement. By combining kinetic and morphologic information with clinical history and conventional imaging (mammography and ultrasound) findings, a recommendation for biopsy can be made with more assurance.

Because malignant lesions can masquerade as benign and vice versa, there can be overlap in the imaging characteristics of benign and malignant lesions. Because there is overlap, the most definitive method of differentiation between benign and malignant is biopsy, which should be performed for any suspicious finding. This chapter addresses the features that will help the reader determine what is suspicious as well as features of a few classic benign entities on MRI.

2. Technique

There is no gold standard technique for performing breast MRI. Many techniques are available and widely used depending on hardware and software capabilities and personal preferences. T1-weighted sequences obtained before and after gadolinium-DTPA administration are favored. High-resolution techniques optimize lesion morphologic analysis and rapid acquisition is used for assessing enhancement profiles. T2-weighted sequences are useful for identifying breast cysts that can be simple or hemorrhagic, in addition to myxoid fibroadenomas and lymph nodes that can be high in signal intensity. In general, invasive breast carcinomas are not very high in signal intensity on T2 except for mucinous carcinoma or necrotic tumors.[6] Intermediate signal carcinomas can sometimes be

Table 6.2. Information Pertinent to Interpretation of the Breast MRI Examination

- Patient history
  - Risk
    - Family history
    - Personal history
      - History of prior biopsy (benign or malignant)
  - Clinical
    - Palpable lump/thickening
    - Nipple discharge
    - Known cancer
  - Hormonal status
    - Menstrual cycle (if pertinent)
    - Exogenous hormone replacement therapy
    - Recent pregnancy
    - Tamoxifen
- Comparison with prior examinations
  - Mammogram
  - Ultrasound
  - Prior MRI
- MRI technique
  - Location of markers and significance
  - Field strength
  - Contrast media used and dose
  - Scan plane—sagittal/axial/coronal
  - Slice thickness
  - Pulse sequence
    - Gradient echo
    - Spin-echo
    - 2D
    - 3D
  - Fat saturation or subtraction
  - Number of postcontrast scans
  - Time interval between postcontrast scans
  - Scan length
  - Matrix resolution
- Postprocessing techniques
  - Multiplanar reconstruction (MPR)
  - Maximum intensity projection (MIP)
  - Time intensity curves
  - Subtraction

Abbreviations: 2D, two-dimensional; 3D, three-dimensional.

seen. Table 6.2 describes information regarding technique that is pertinent to the report.

In addition to providing descriptions of the morphologic and kinetic findings, the MRI report should have a final recommendation to convey the level of suspicion to the referring physician. If a recommendation for biopsy is made, it should be clearly reported in the final impression and a final assessment category should be specified, as in mammography.

3. Breast Histopathology and Magnetic Resonance Imaging

Breast disease pathology is superbly seen and delineated by using breast MRI. To allow identification and characterization of small lesions, slice thickness should be approximately 2mm so that volume averaging is not an issue. Because breast cancer can grow along a duct system extending from the terminal duct lobular unit either into the breast as an invasive mass or extending along the duct system in a segmental fashion to the nipple, breast MRI is exquisitely poised to depict the spread of disease, as long as there is increased vascularity associated with the disease. Three-dimensional maximum intensity projection (MIP) reconstructions can nicely demonstrate such uctal enhancement patterns (Figure 6.1).

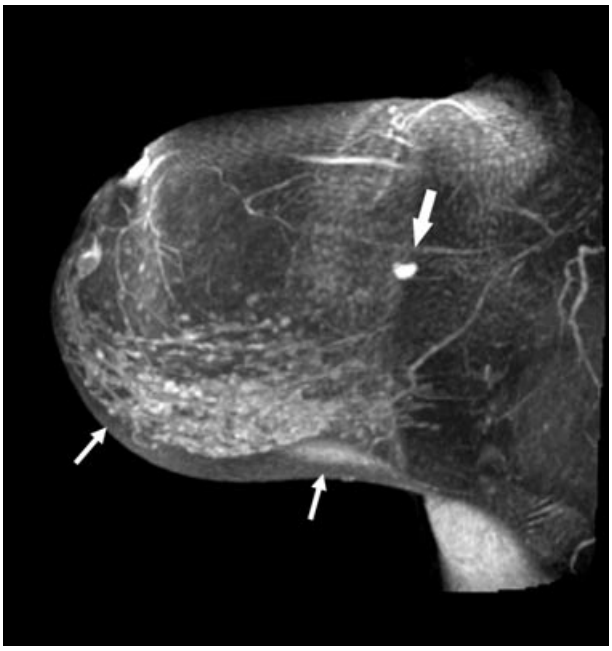


FIGURE 6.1. Maximum intensity projection (MIP) of segmental ductal enhancement in the inferior breast compatible with extensive ductal carcinoma in situ (arrows). All images in the illustrations of the lexicon are performed postcontrast with fat suppression sagittal T1-weighted technique unless otherwise indicated. Note intramammary lymph node (thick arrow).

Compared with mammography breast MRI is superior at delineating disease extent. Mammography may demonstrate a mass that proves to be an invasive carcinoma that may only be a small component of the total tumor load. Breast MRI not only shows us the invasive component but may also demonstrate the surrounding uncalcified segmental ductal carcinoma in situ (DCIS) from which the invasive carcinoma grew. Multifocal disease is often represented as a segmental area of enhancement representing DCIS in association with several heterogeneously enhancing masses representing the sites where the basement membrane has been crossed and the tumor has invaded the breast.

A basic understanding of cancer growth and spread in the breast aids in the analysis of the morphologic features seen with breast MRI. Similarly, knowledge of the histopathology of benign lesions, such as the different types of fibroadenomas, can aid in the interpretation of benign findings. For example, a slowly enhancing mass may represent a sclerotic hyalinized fibroadenoma, whereas a rapidly enhancing mass may represent a myxoid fibroadenoma. Fibroadenomas may also contain fibrous nonenhancing bands: If these are identified with certainty and all other features appear benign, a benign diagnosis can be made comfortably.

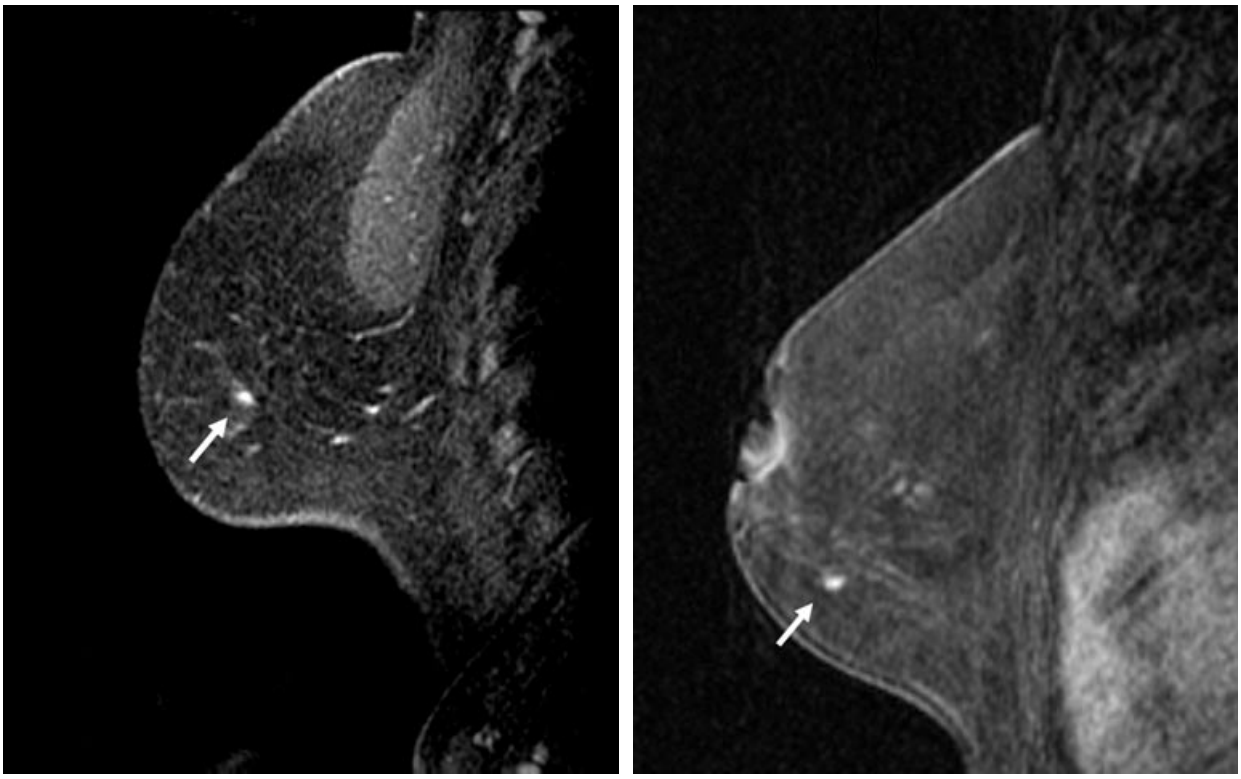
4. Morphologic Features

Morphologic analysis is best performed with high spatial resolution techniques that allow evaluation of the mass shape and border so that suspicious spiculated or irregular masses can be differentiated from smooth benign-appearing masses. Also, with high spatial resolution, the borders and internal architecture of the lesion can be assessed and the pattern of enhancement can be readily characterized.

5. Description of Terms

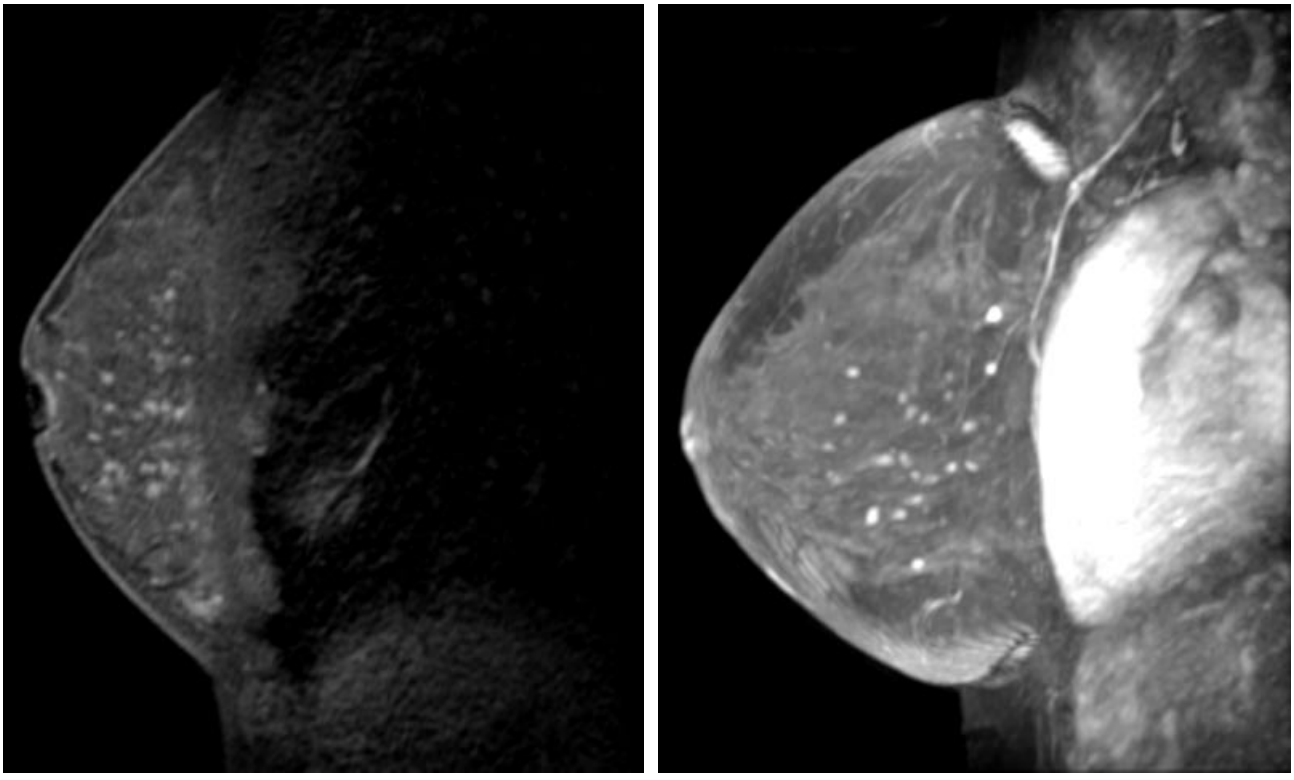
5.1. Focus/Mass

A focus is a single tiny punctate enhancement that is nonspecific and too small to be characterized. A focus is clearly not a space-occupying lesion or mass (Figure 6.2). An enhancing lesion on MRI can be described as a mass if it displaces tissue and has space-occupying properties. If there are multiple foci in a breast, the term *stippled* can be applied (Figure 6.3).



A B

FIGURE 6.2. (A and B) Foci (arrows).



A B

FIGURE 6.3. (A and B) Stippled enhancement.

5.2. Shape/Margin

The shape and margins of masses can be described. Mass shape can be described as round, oval, lobular, or irregular (Figure 6.4). Margins of masses are smooth, irregular, or spiculated. Spiculated and irregular masses (Figure 6.5) are suspicious for carcinoma, whereas a smooth margin is more suggestive of a benign lesion (Figure 6.6). Margin analysis is dependent on spatial resolution and irregular borders can appear relatively smooth when insufficient resolution is used. Therefore, carcinomas may present with benign imaging features on MRI, particularly when small (Figure 6.7). It should be emphasized that the resolution of MRI is generally not as high as the resolution of mammography and that border definition is not as absolute. Therefore, malignant masses may be more prone to demonstrate benign features on MRI.[7,8]

In general, margin and shape analysis should be performed on the first postcontrast image to avoid

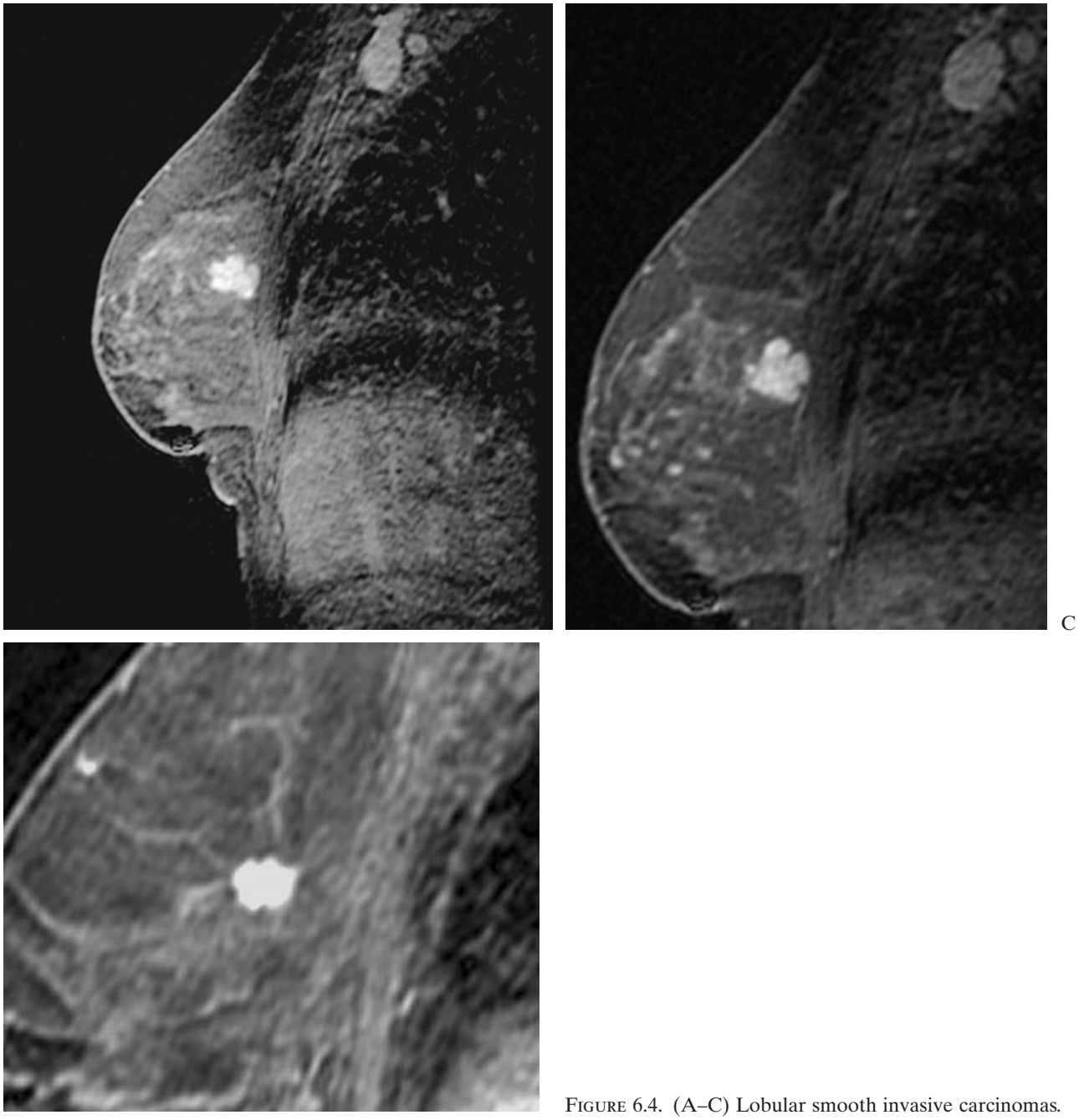


FIGURE 6.4. (A–C) Lobular smooth invasive carcinomas.

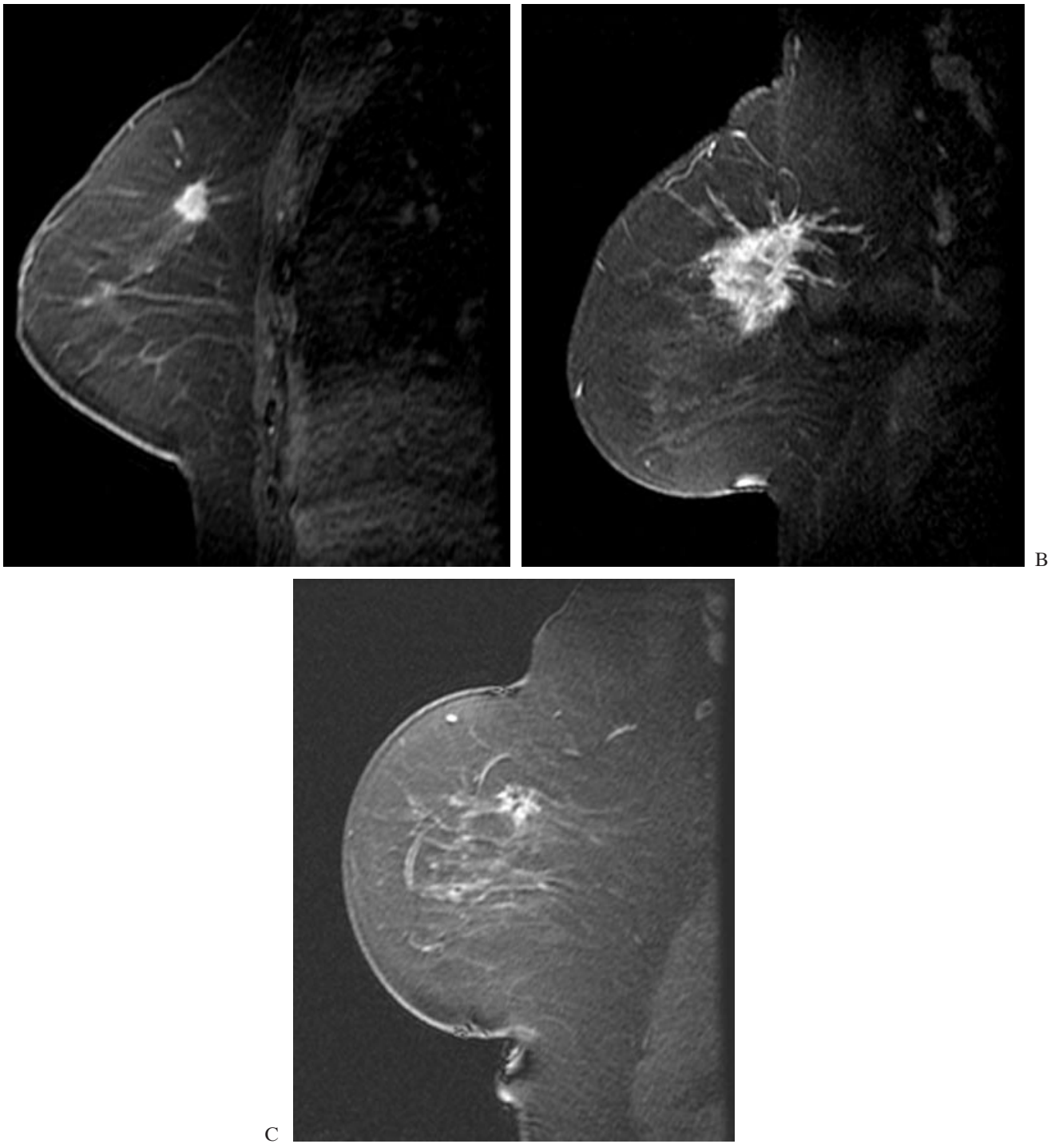


FIGURE 6.5. (A–C) Irregular spiculated invasive carcinomas.

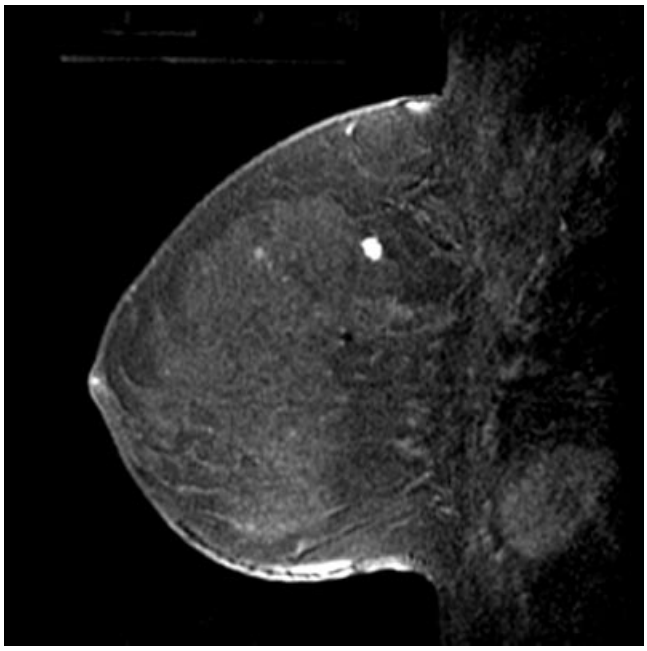


FIGURE 6.6. Oval smooth lymph node.

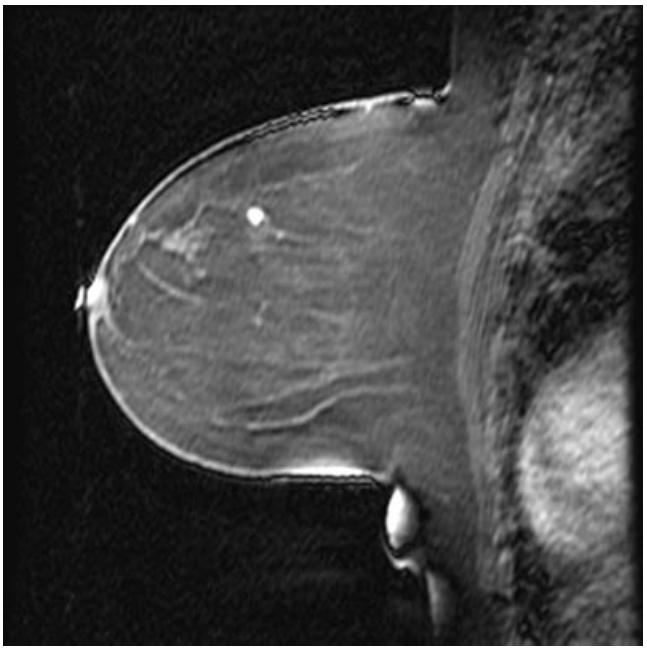
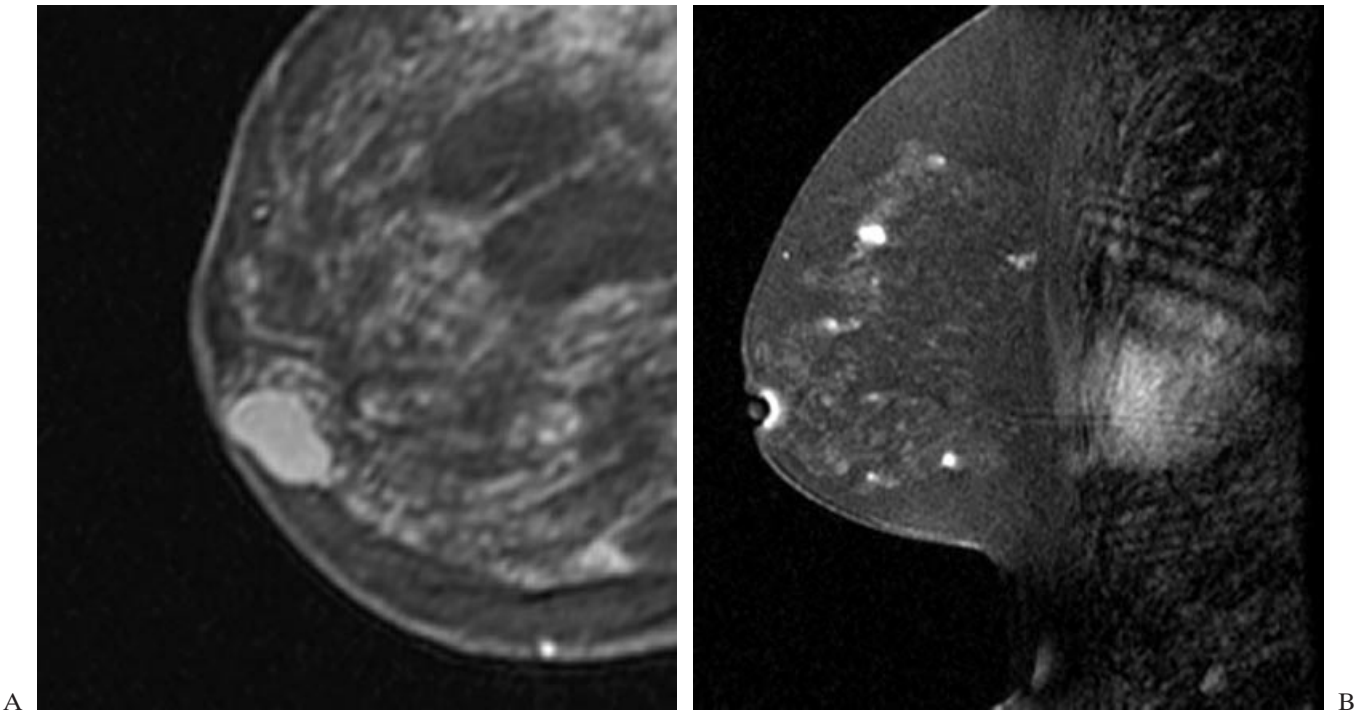


FIGURE 6.7. Small round smooth carcinoma.

washout and progressive enhancement of the surrounding breast tissue, which can obscure lesion analysis. Additionally, as time elapses after contrast enhancement, the periphery of the lesion may become more indistinct.[9]

5.3. Internal Enhancement

Internal enhancement of masses can be described as homogeneous or heterogeneous. Homogeneous enhancement is confluent and uniform (Figure 6.8). Heterogeneous



A B

FIGURE 6.8. Homogeneous enhancement. (A) Fibroadenoma. (B) DCIS.

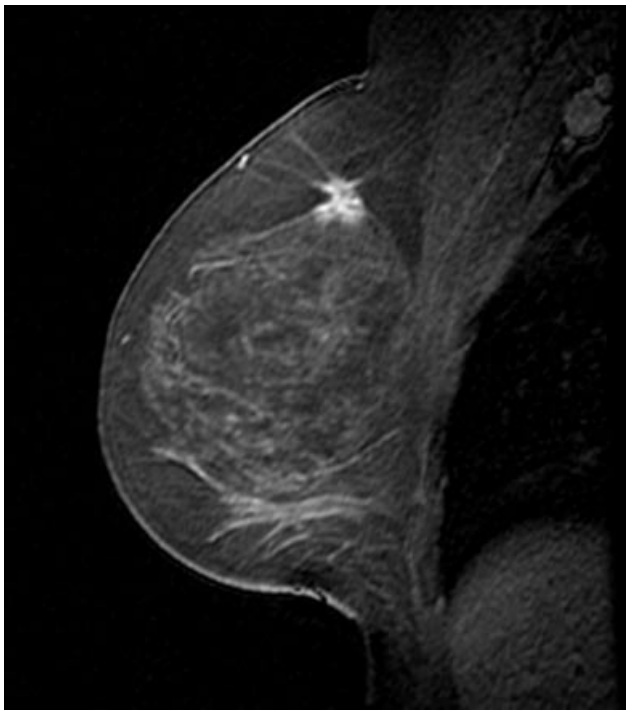
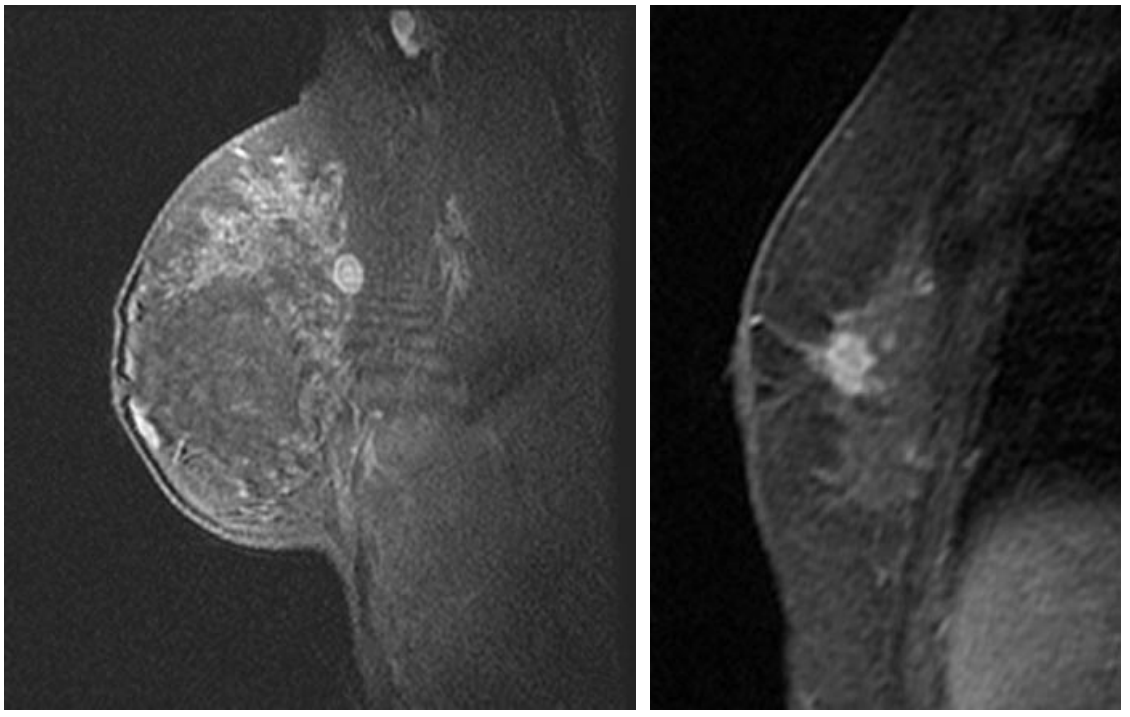


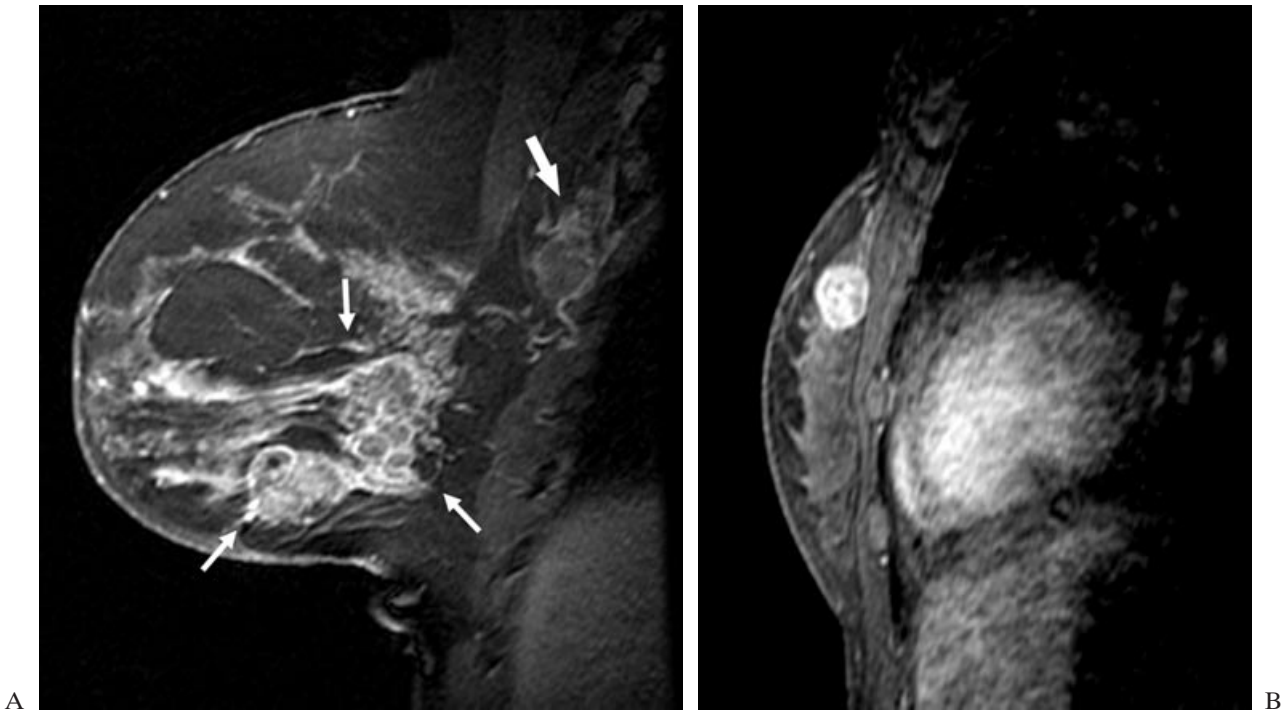
FIGURE 6.9. Heterogeneous enhancement in invasive carcinoma.

enhancement is non-uniform with areas of variable signal intensity (Figure 6.9). Masses may display rim enhancement, a particularly suspicious finding for malignancy (Figure 6.10). Other suspicious findings include enhancing septations (Figure 6.11) or central enhancement (Figure 6.12), though these signs occur less commonly. Homogeneous enhancement is suggestive of a benign process; however, again, in small lesions, one must be careful as



A B

FIGURE 6.10. (A and B) Rim enhancement. Invasive ductal carcinomas.



A B

FIGURE 6.11. Enhancing internal septations. (A) Invasive ductal carcinoma (small arrows) and metastatic disease to the axilla (large arrow). (B) Invasive ductal carcinoma.

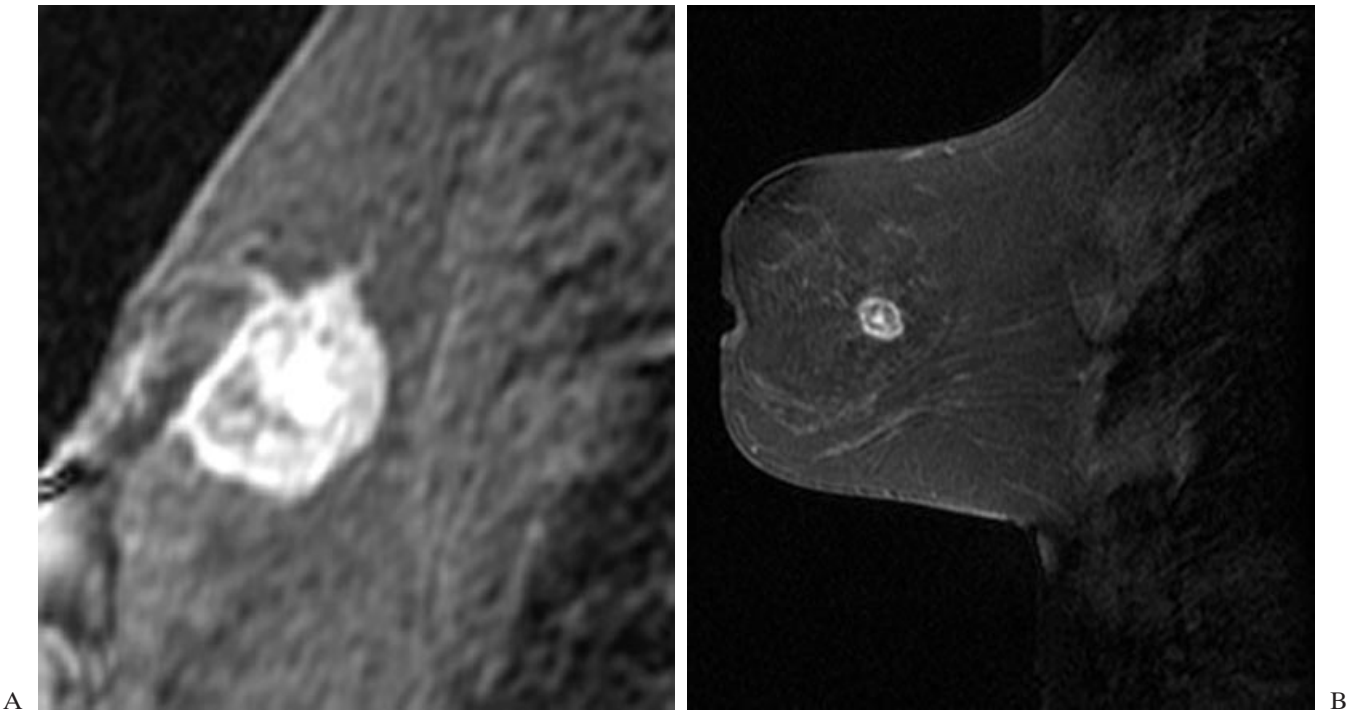


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FIGURE 6.12. (A and B) Central enhancement. Invasive ductal carcinomas.

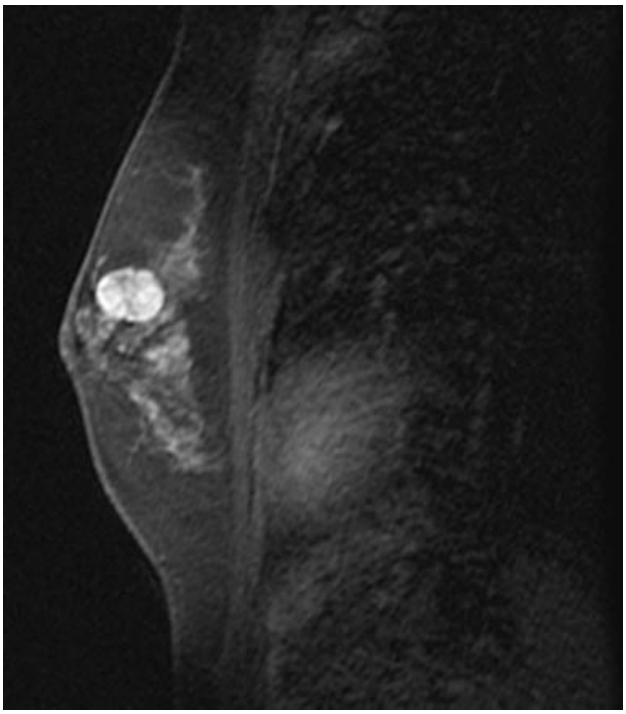
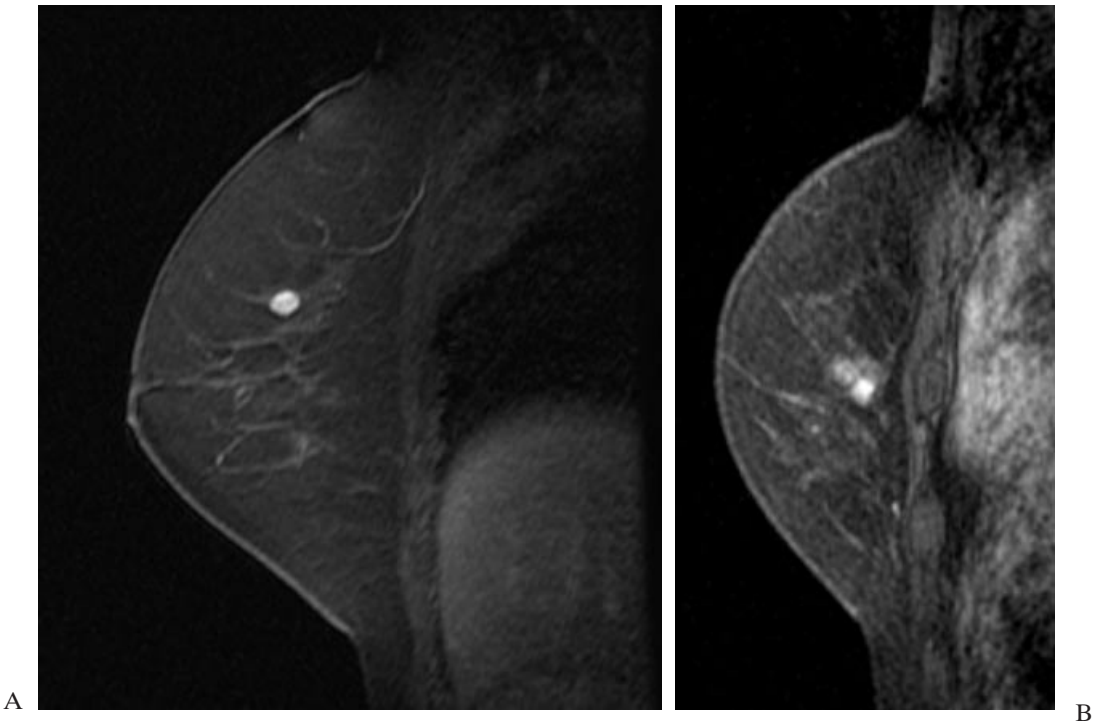


FIGURE 6.13. Dark nonenhancing septations in fibroadenoma.

spatial resolution may limit evaluation. Heterogeneous enhancement is more characteristic of malignant lesions especially if rim enhancement is present.

Dark internal septations are classic for fibroadenomas (Figure 6.13) though are seen in the minority of cases (Figure 6.14). When present, masses can be considered benign with a high degree of certainty (>95% according to Nunes).[10–12] Careful analysis of the lesion is important so that cancers are not missed due to morphologic overlap (Figure 6.15). Similarly, nonenhancing masses are also



A B

FIGURE 6.14. (A) Smooth mass and fibroadenomas appearing as (B) irregular mass.

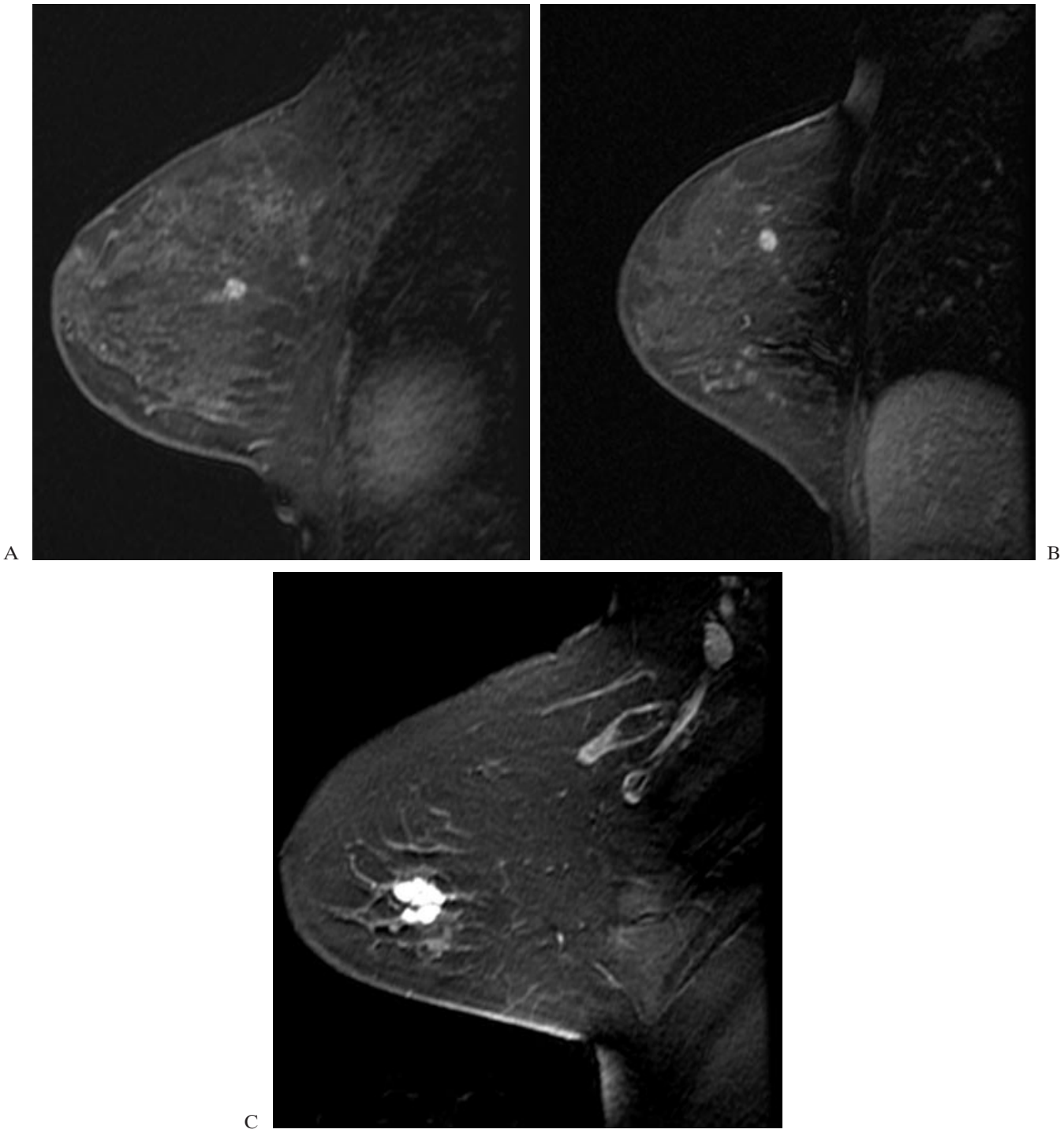


FIGURE 6.15. (A–C) Invasive carcinomas appearing as possible fibroadenomas. Note lobular shape and smooth margins in all cases.

likely benign fibroadenomas that have a high hyaline content (Figure 6.16). Other benign lesions include an inflammatory cyst that enhances peripherally (Figure 6.17) and benign fat necrosis (Figure 6.18) that can exhibit rim enhancement with central low signal indicating fatty content. These latter two lesions should be recognized as potential pitfalls in interpretation of *rim*-enhancing lesions. The cyst can generally be identified on a T2-weighted image and fat necrosis can often be recognized based on the patient's history and mammographic findings. It may be helpful to include a non–fat-suppressed sequence to assess the central fat content in cases of fat necrosis.

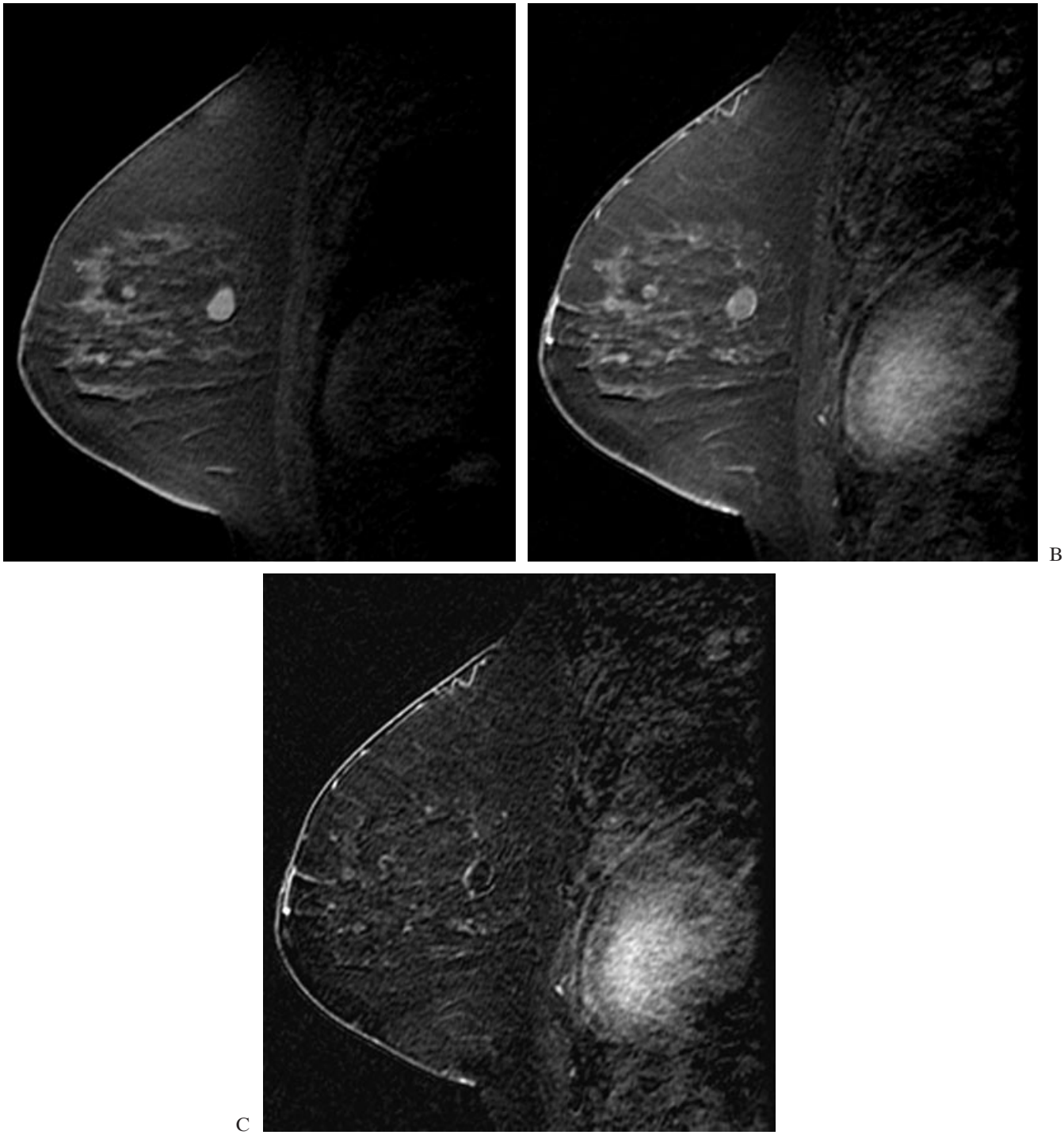
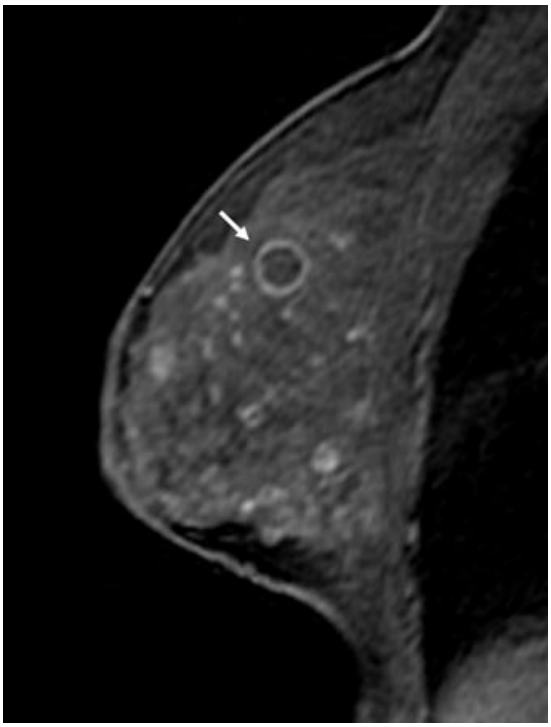


FIGURE 6.16. Nonenhancing mass. Hyalinized fibroadenoma. (A) Precontrast. (B) Postcontrast. (C) Subtraction.



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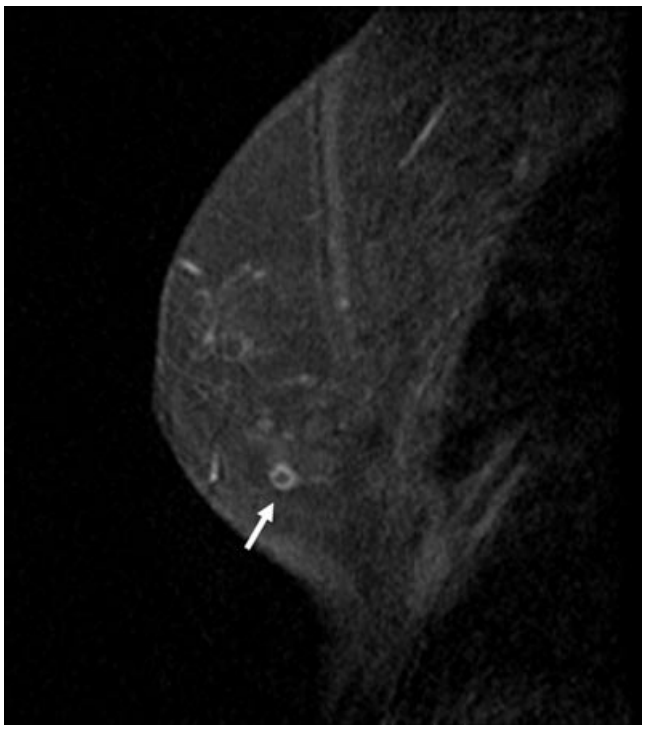


B

FIGURE 6.17. (A and B) Inflammatory cysts (arrows) in two patients.

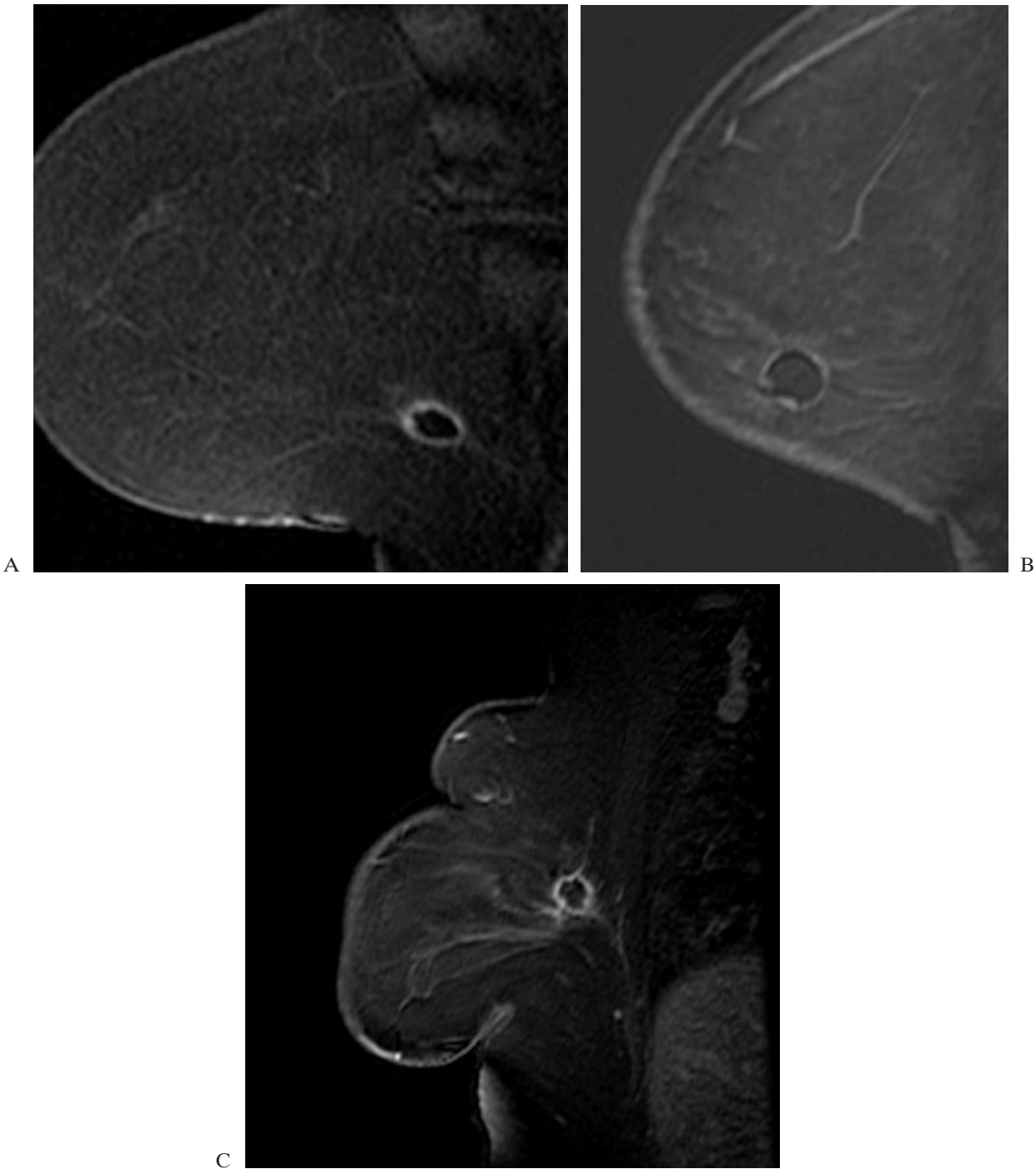


FIGURE 6.18. (A–C) Fat necrosis following surgery.

5.4. Nonmass Enhancement

If the enhancement is neither a focus nor mass, then it is classified as nonmass-like enhancement. Nonmass enhancement is classified according to the distribution of the enhancement and can be described as linear-ductal, linear-nonspecific, regional, segmental, or diffuse. Linear enhancement most often is related to the ductal system (Figure 6.19) although can be seen with nonductal pathology (Figure 6.20). Ductal enhancement corresponds to one or more ducts in orientation and is suspicious for DCIS (Figure 6.21). Ductal-nonspecific would not follow this pattern and is less suspicious for malignancy (Figure 6.22). Segmental refers to enhancement that is triangular in

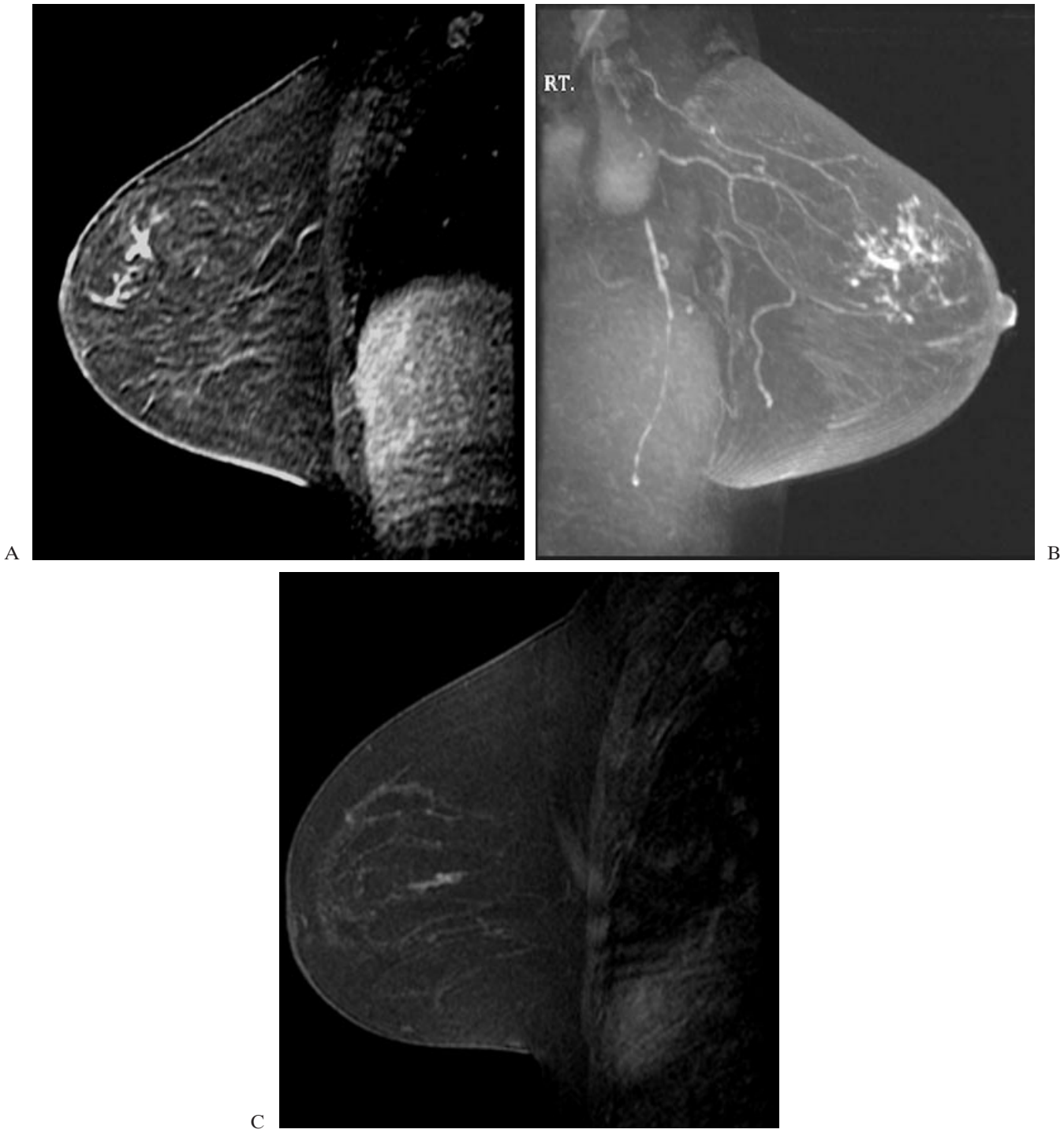
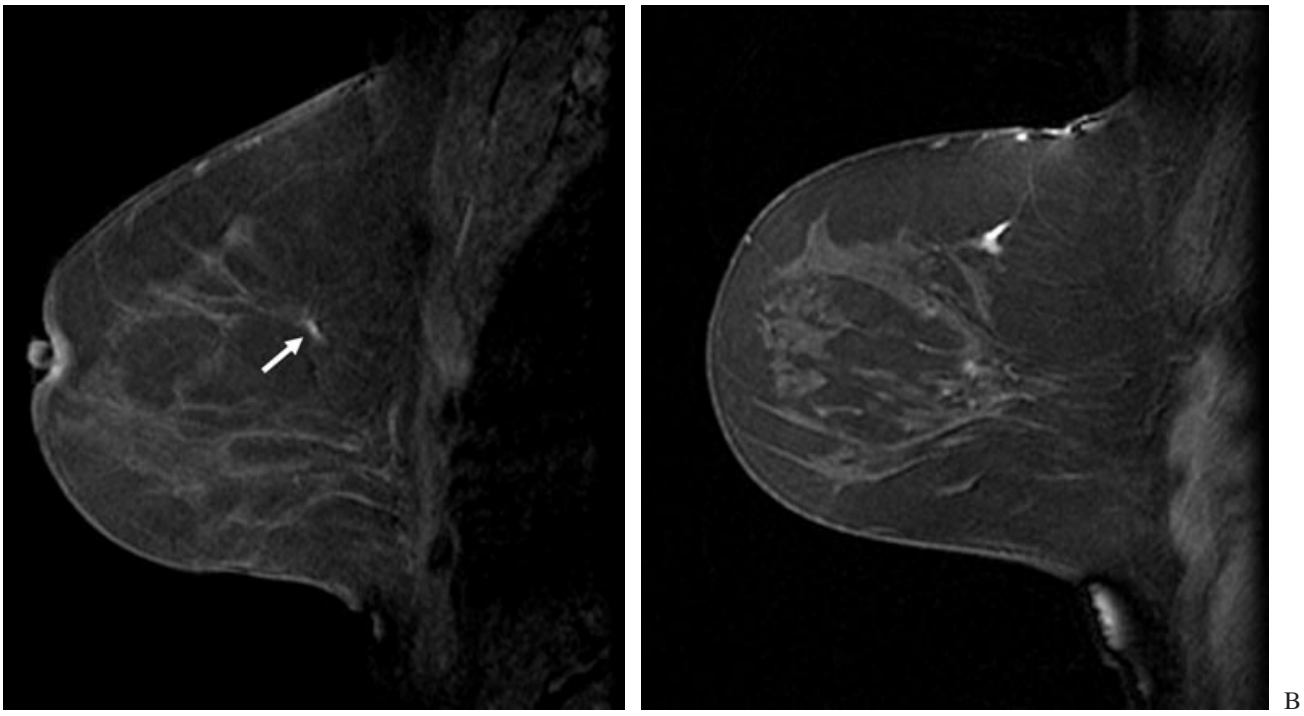


FIGURE 6.19. Ductal enhancement in DCIS. (A) Segmental ductal branching. (B) Maximum intensity projection image of segmental ductal enhancement. (C) Linear irregular enhancement.



A B

FIGURE 6.20. (A and B) Linear enhancement in scars (arrow) following surgery in two patients.

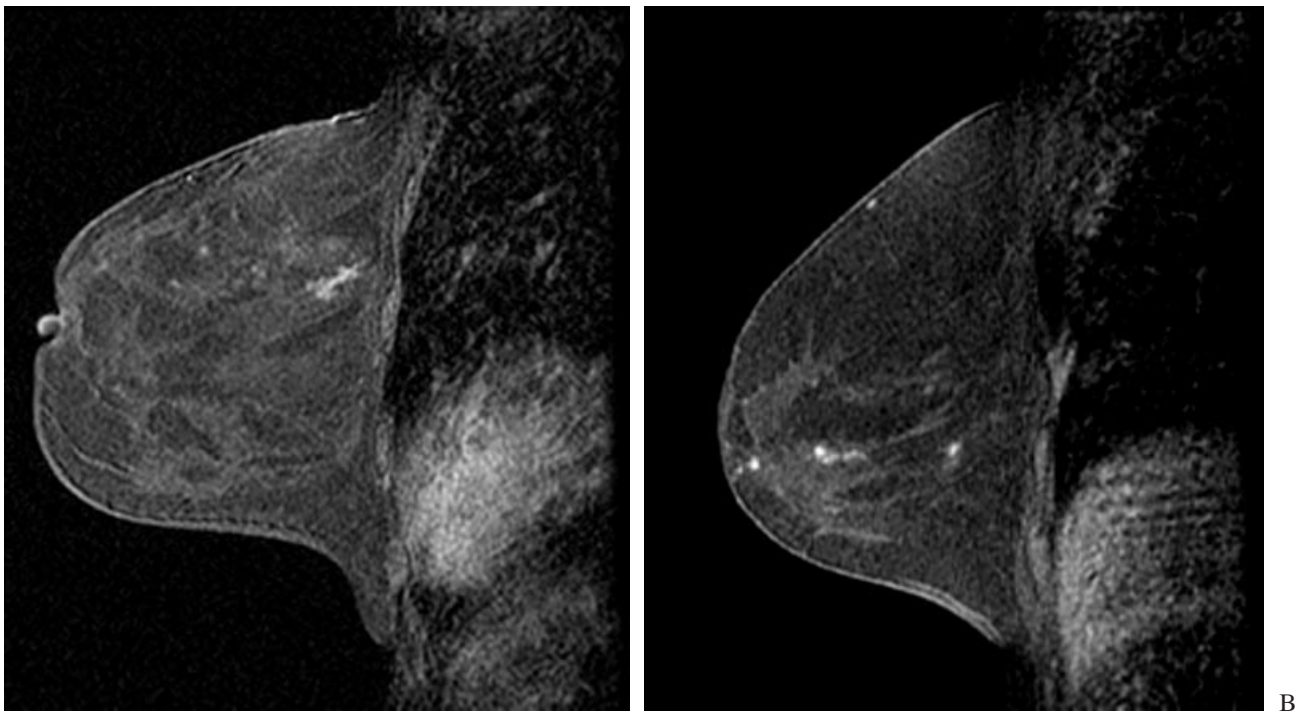


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FIGURE 6.21. (A–C) Ductal enhancement representing DCIS in two patients.

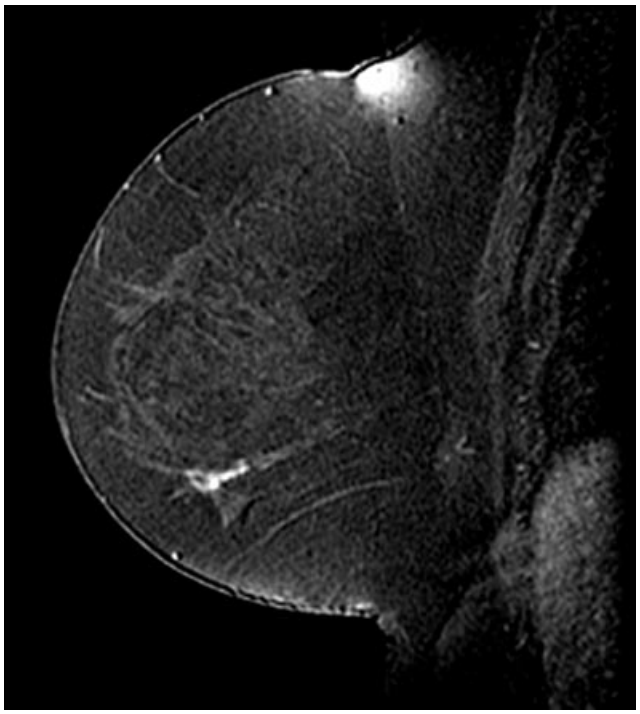
C 

FIGURE 6.21. (*Continued*)

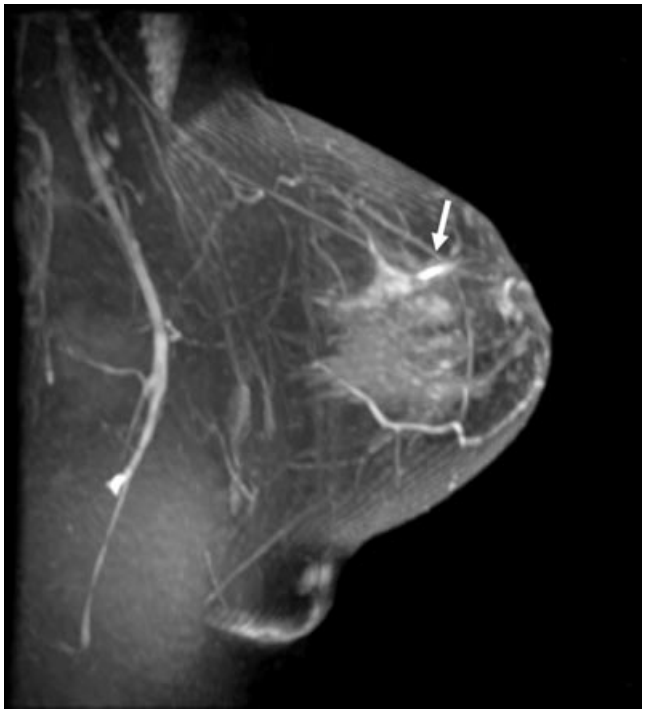


FIGURE 6.22. MIP demonstrating linear enhancement in scar (arrow).

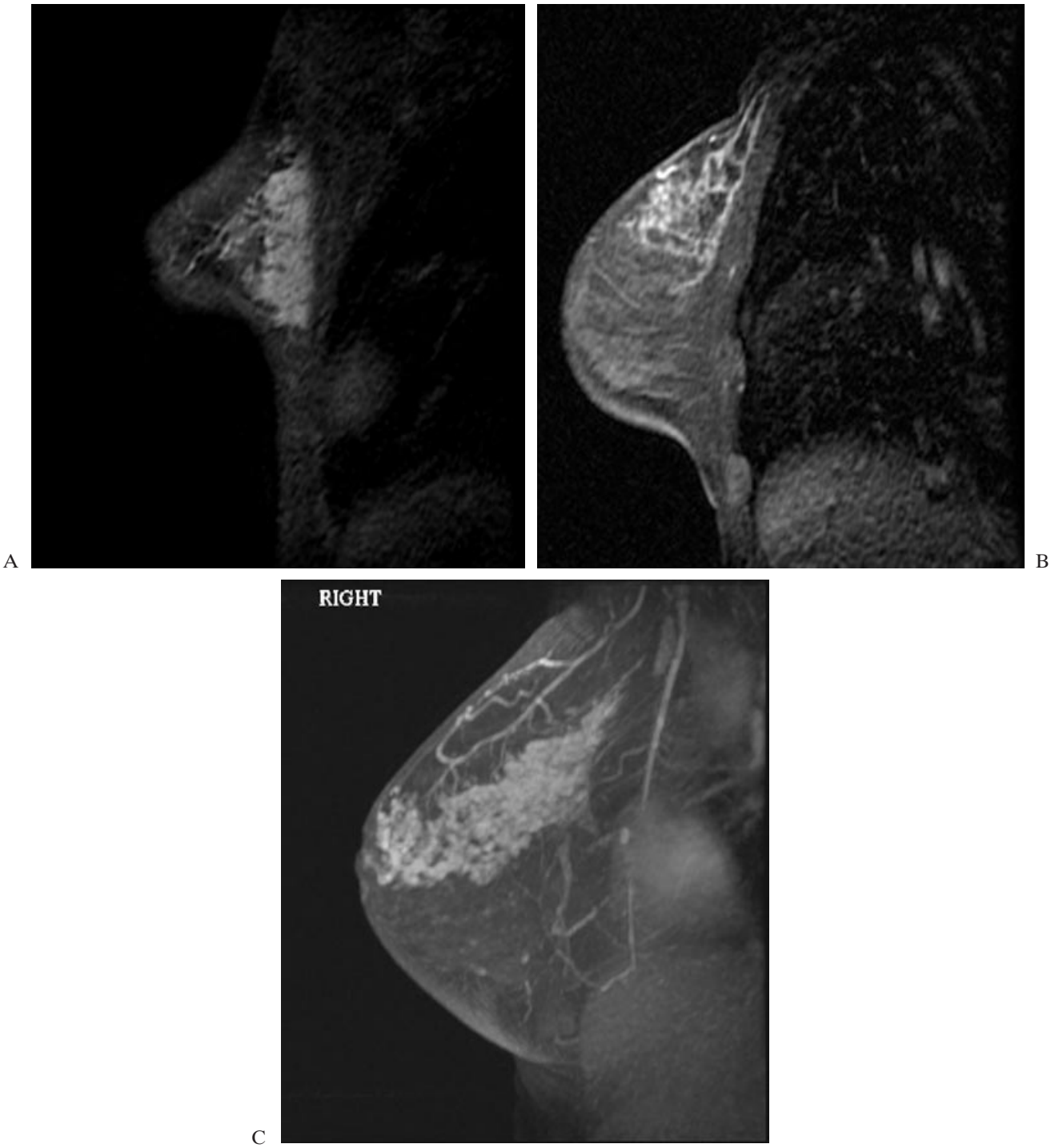


FIGURE 6.23. (A–C) Segmental enhancement representing DCIS in three patients. (C) Maximum intensity projection.

shape with the apex at the nipple and is suspicious for DCIS within a single branching duct system (Figure 6.23). Regional enhancement is enhancement that does not correspond to a single duct system, however, may be within multiple ducts (Figure 6.24).

Linear enhancement can be further described as smooth, irregular, or clumped. As with smooth masses, smooth linear enhancement is suggestive of a benign process. Irregular enhancement refers to any nonsmooth enhancement and may be continuous or discontinuous (Figure 6.25). Clumped enhancement refers to an aggregate of enhancing masses or foci that may be confluent in a cobblestone pattern (Figure 6.26). Linear enhancement is suggestive of DCIS, especially if clumped or irregular (Figure 6.27).

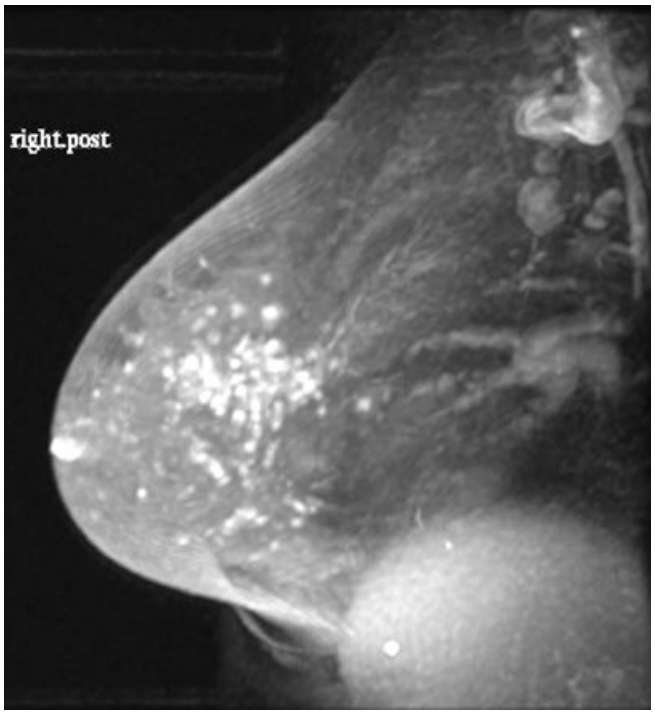
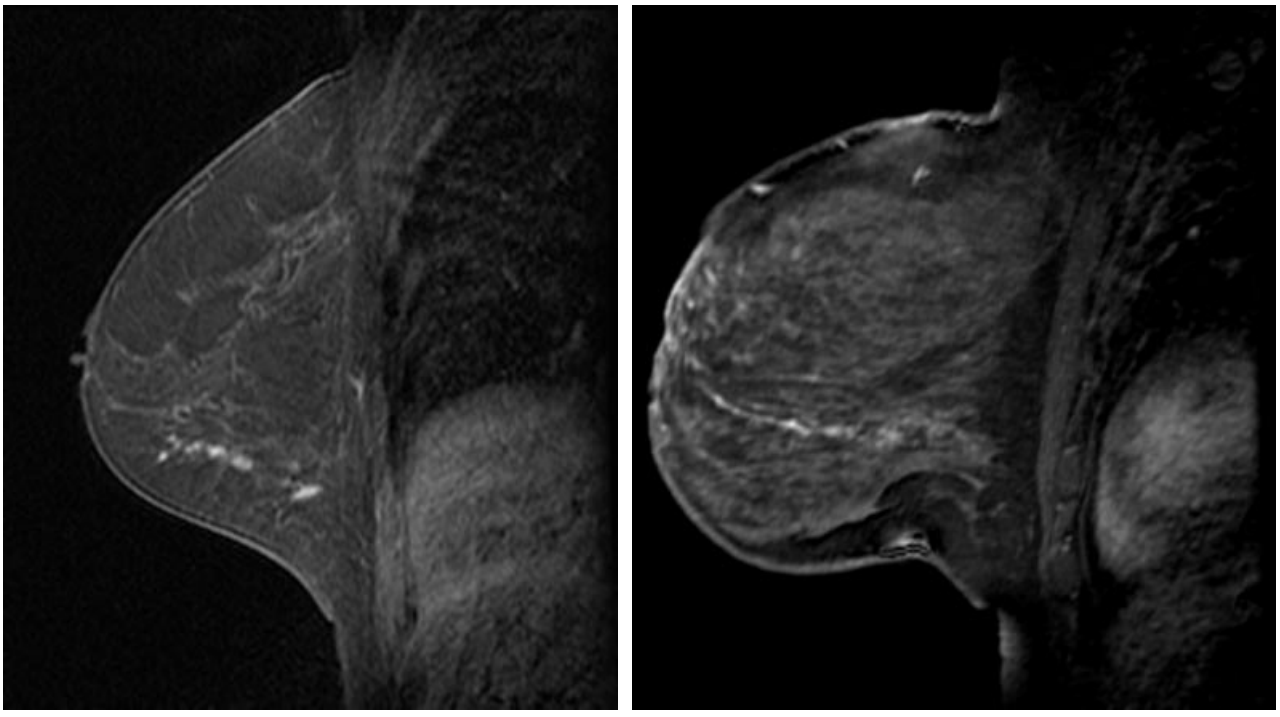


FIGURE 6.24. MIP demonstrating regional enhancement in DCIS.

Segmental, regional, or diffuse enhancement can be further described as homogeneous, heterogeneous-stippled/punctate, clumped, septal/dendritic, or non specific. Stippled refers to multiple, often innumerable punctate foci that are approximately 1 to 2mm in size and appear scattered throughout an area of the breast that does not conform usually to a duct system (Figure 6.28). Stippled enhancement is more characteristic of benign normal



A B

FIGURE 6.25. (A and B) Ductal enhancement in DCIS.

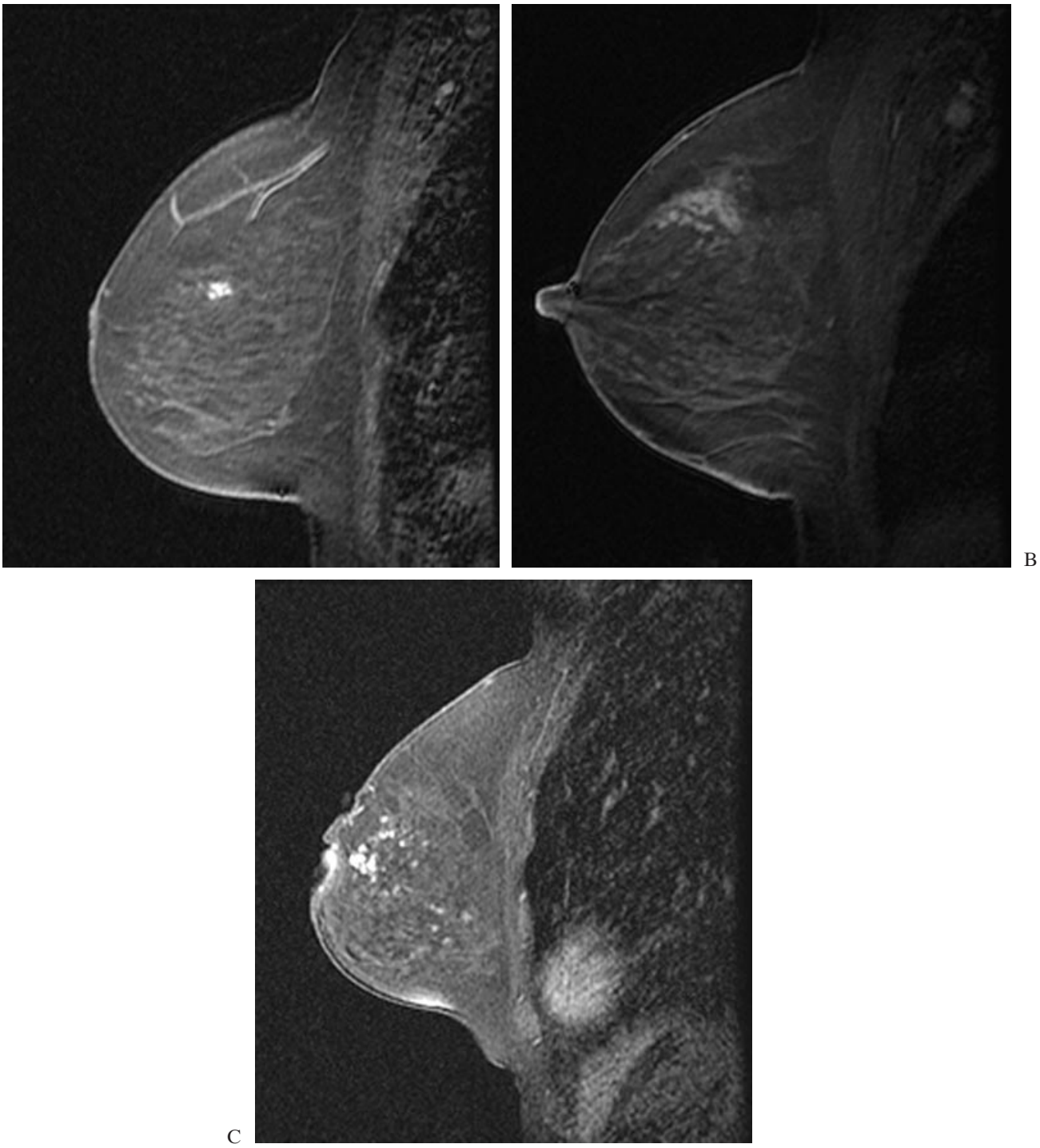


FIGURE 6.26. (A–C) Clumped enhancement in three patients representing DCIS.

variant parenchymal enhancement or fibrocystic changes. Regional enhancement and diffuse enhancement are more characteristic of benign disease such as proliferative changes, although multicentric DCIS may have this appearance (Figure 6.29). Other findings that may be present are listed in Table 6.1 and are demonstrated (Figures 6.30–6.41).

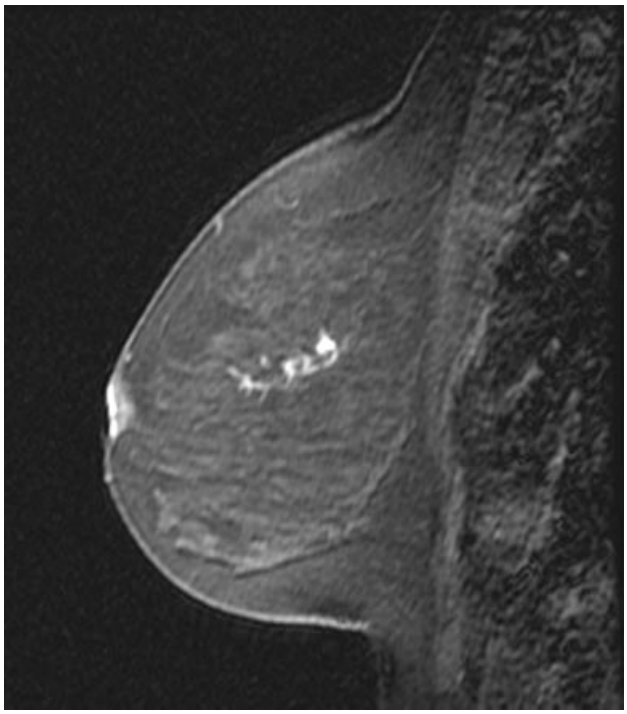
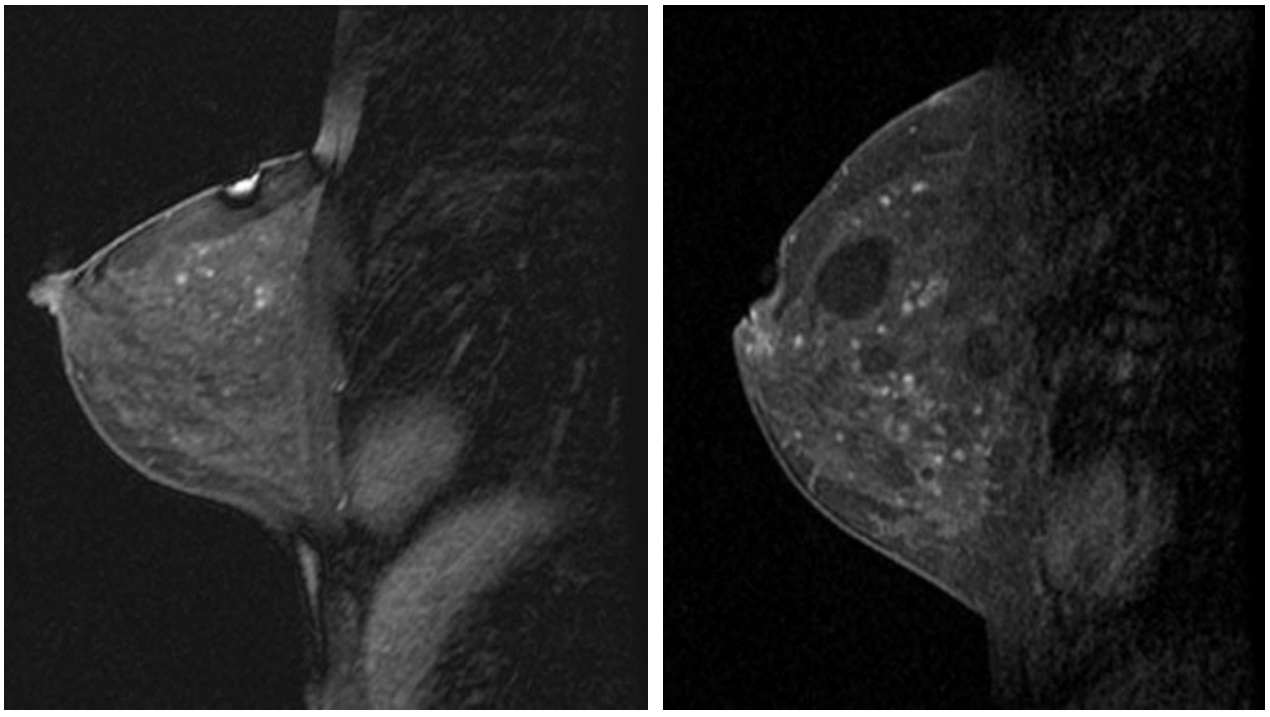


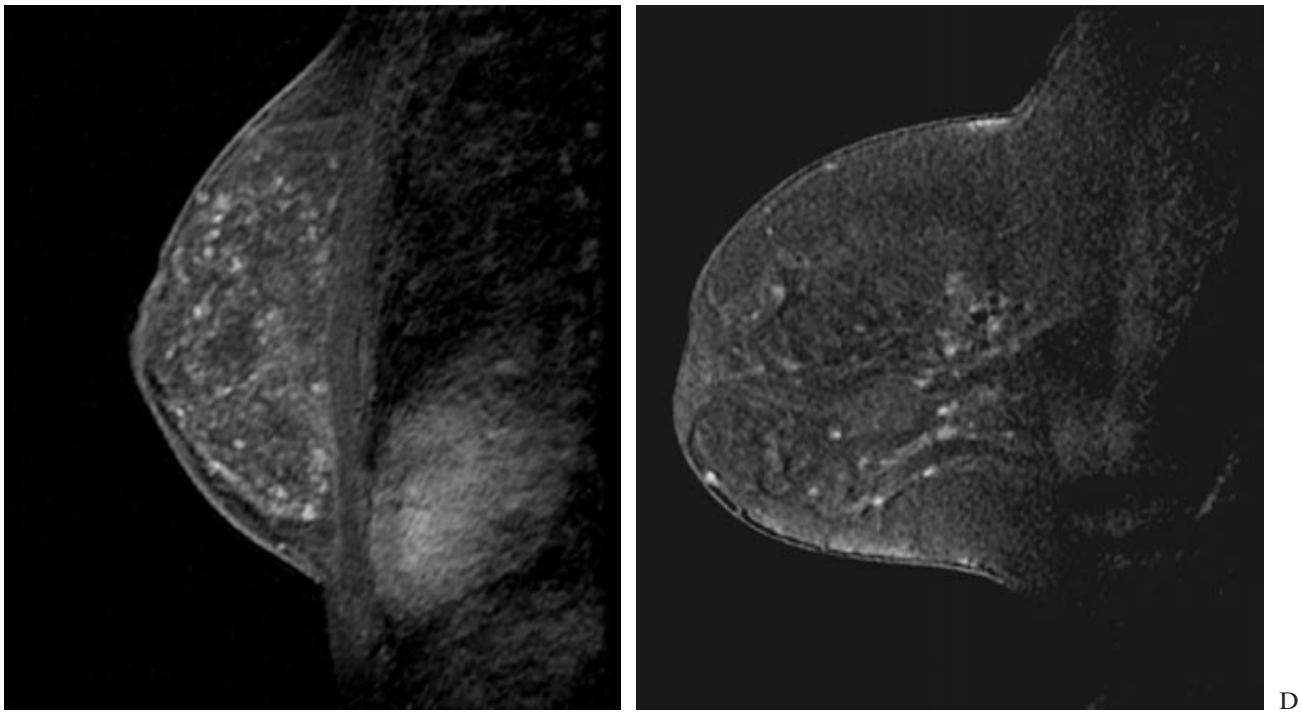
FIGURE 6.27. Linear clumped enhancement in DCIS.



A B

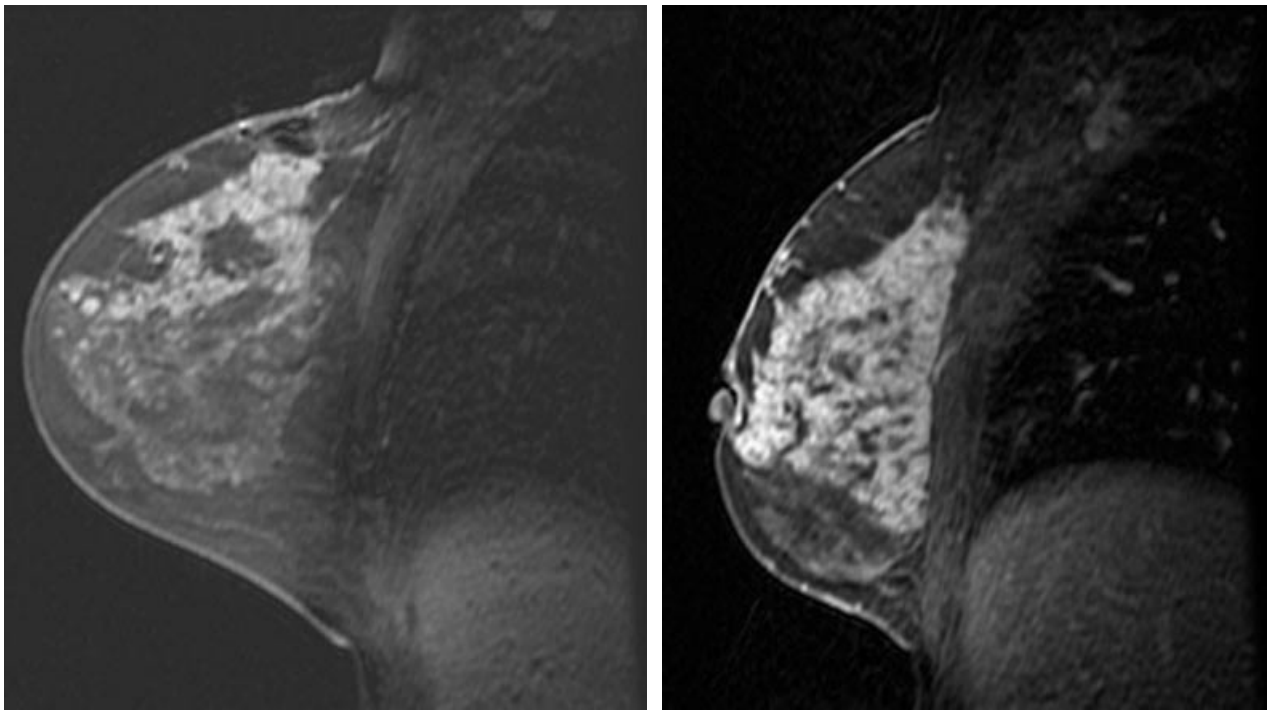
FIGURE 6.28. (A–D) Examples of stippled enhancement.

(*Continued*)



C D

FIGURE 6.28. (*Continued*)



A B

FIGURE 6.29. (A and B) Regional enhancement in two cases of DCIS.

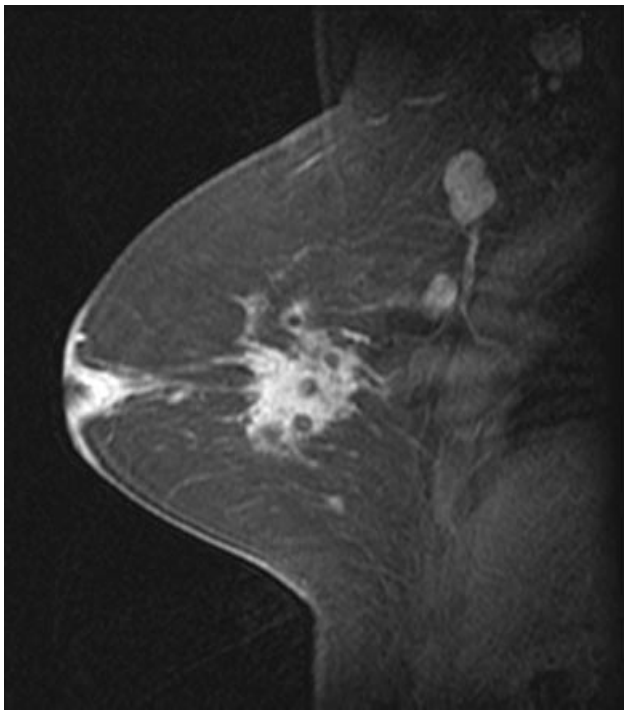


FIGURE 6.30. Nipple retraction due to underlying invasive lobular carcinoma. Note axillary adenopathy.

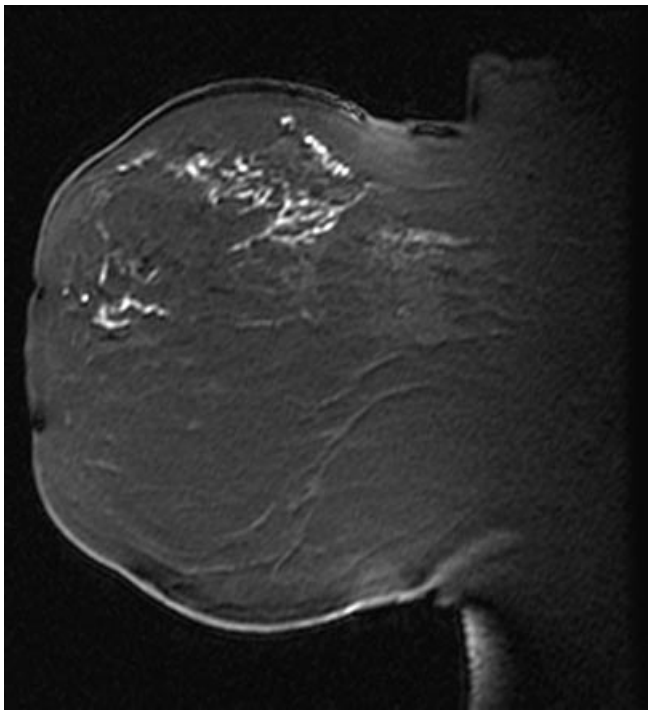


FIGURE 6.32. Duct ectasia. High signal in mildly dilated ducts in a segmental distribution on precontrast images.

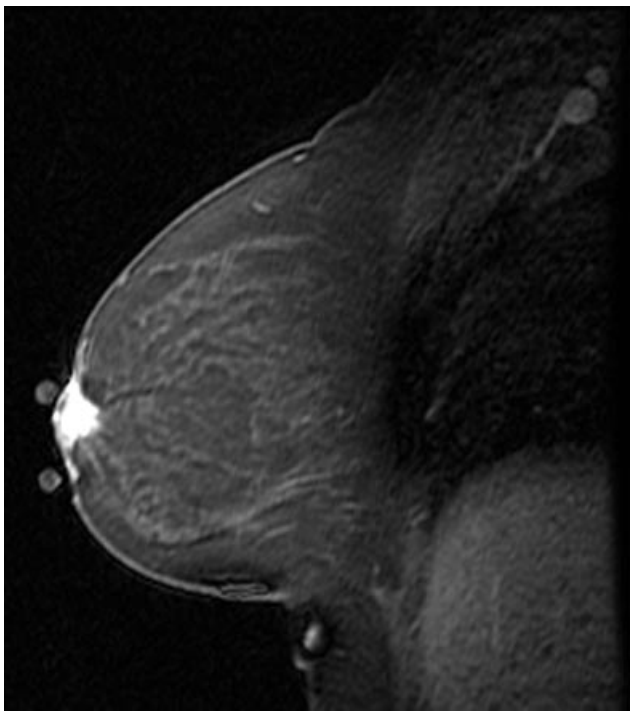


FIGURE 6.31. Nipple invasion. Subareolar invasive ductal carcinoma.

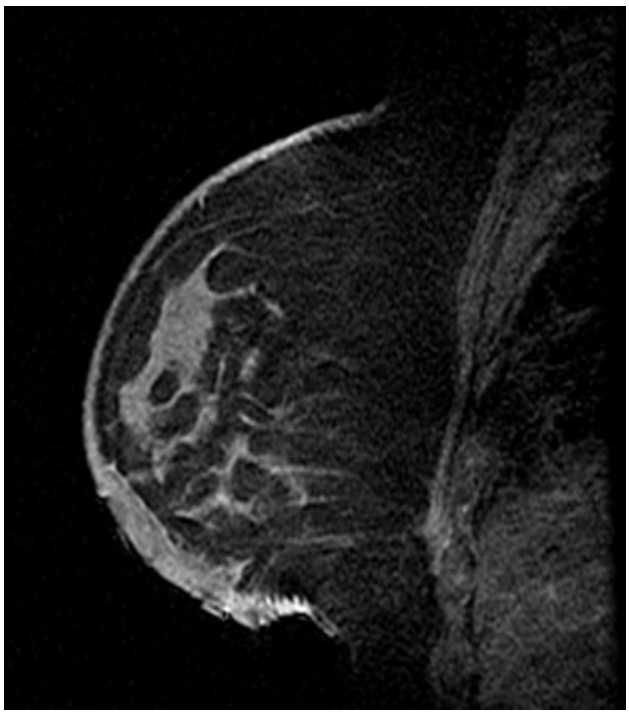


FIGURE 6.33. Focal skin thickening. Status postsurgery and radiation therapy. Note absence of enhancement in skin.

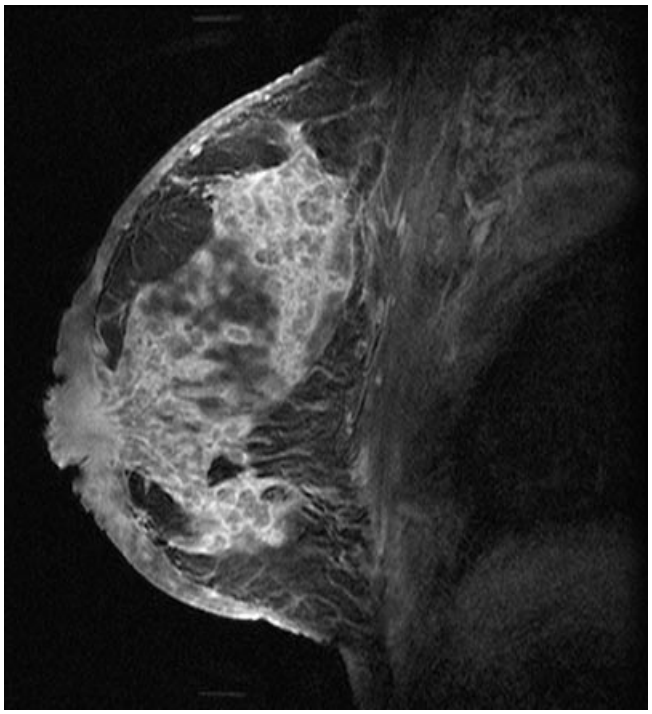


FIGURE 6.34. Diffuse skin thickening with enhancement. Inflammatory breast carcinoma. Note reticular dendritic pattern of enhancement in the breast.

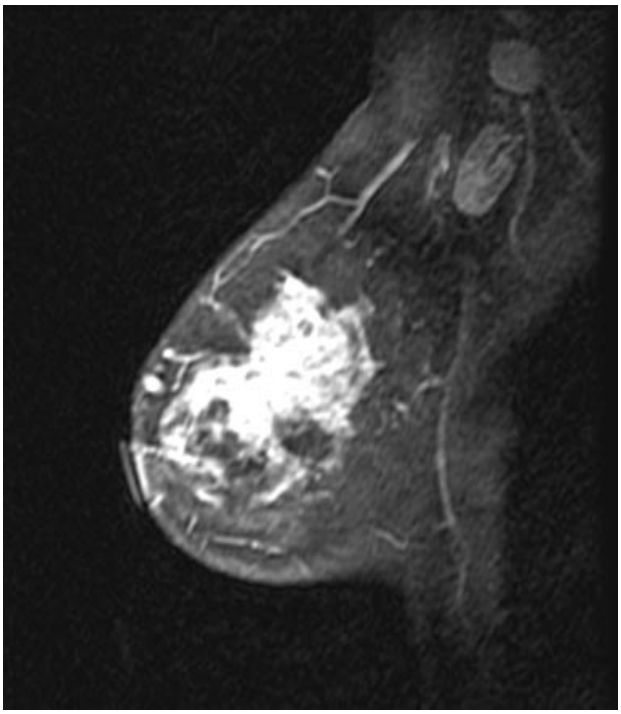


FIGURE 6.36. Locally advanced breast carcinoma with axillary adenopathy.

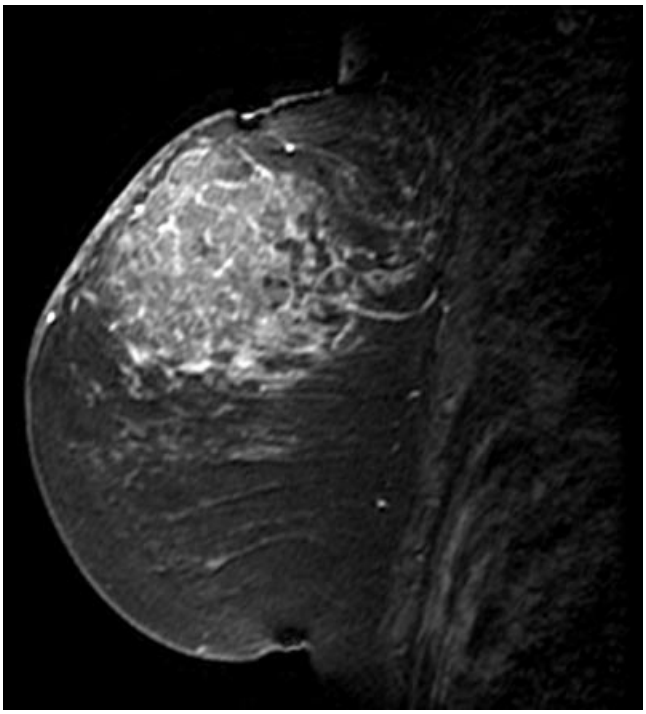


FIGURE 6.35. Focal skin invasion. Underlying inflammatory carcinoma involving upper breast.

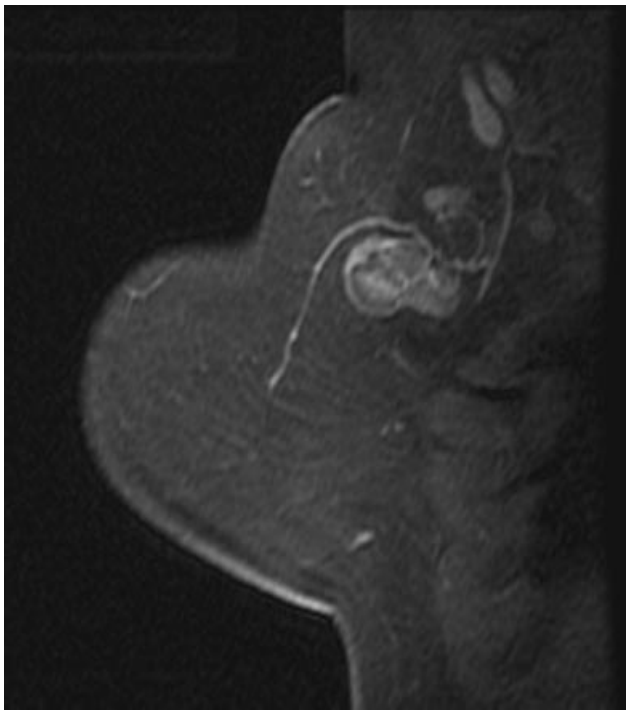


FIGURE 6.37. Axillary adenopathy.

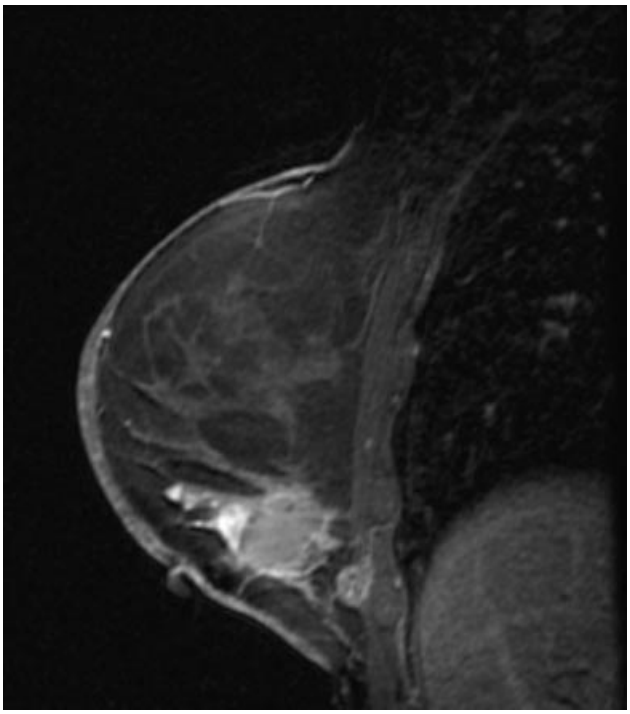
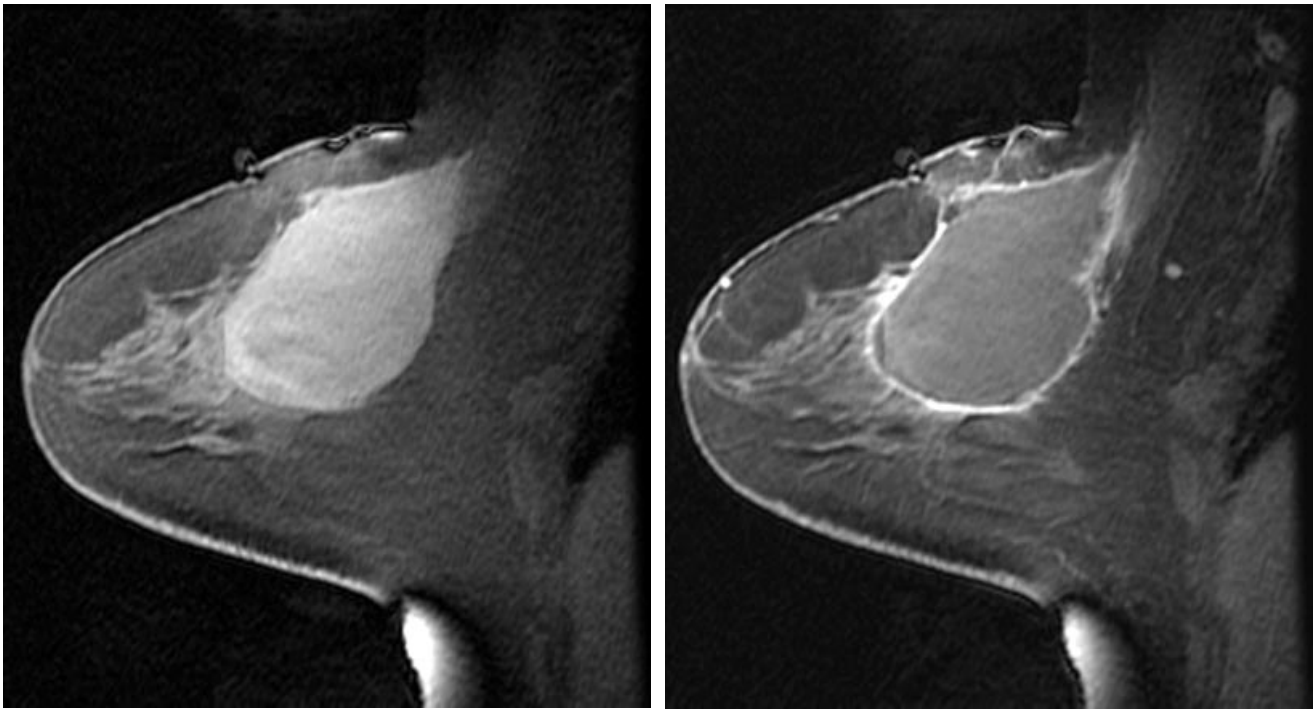


FIGURE 6.38. Chest wall invasion. Note dominant carcinoma in lower breast. Posterior satellite lesion invades intercostal muscle.



A B

FIGURE 6.39. Hematoma. (A) Precontrast image demonstrates high signal intensity of postoperative hematoma following surgery. (B) Note thin rim of enhancement around hematoma cavity representing immediate postoperative changes.

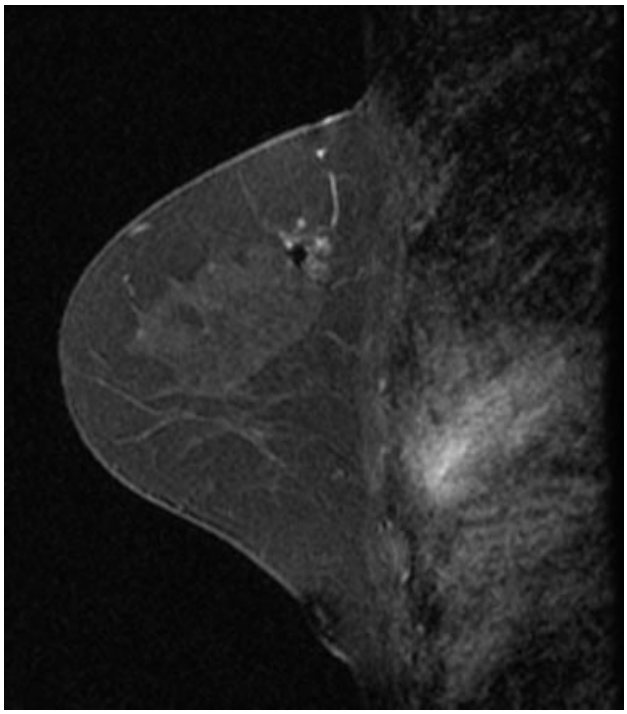
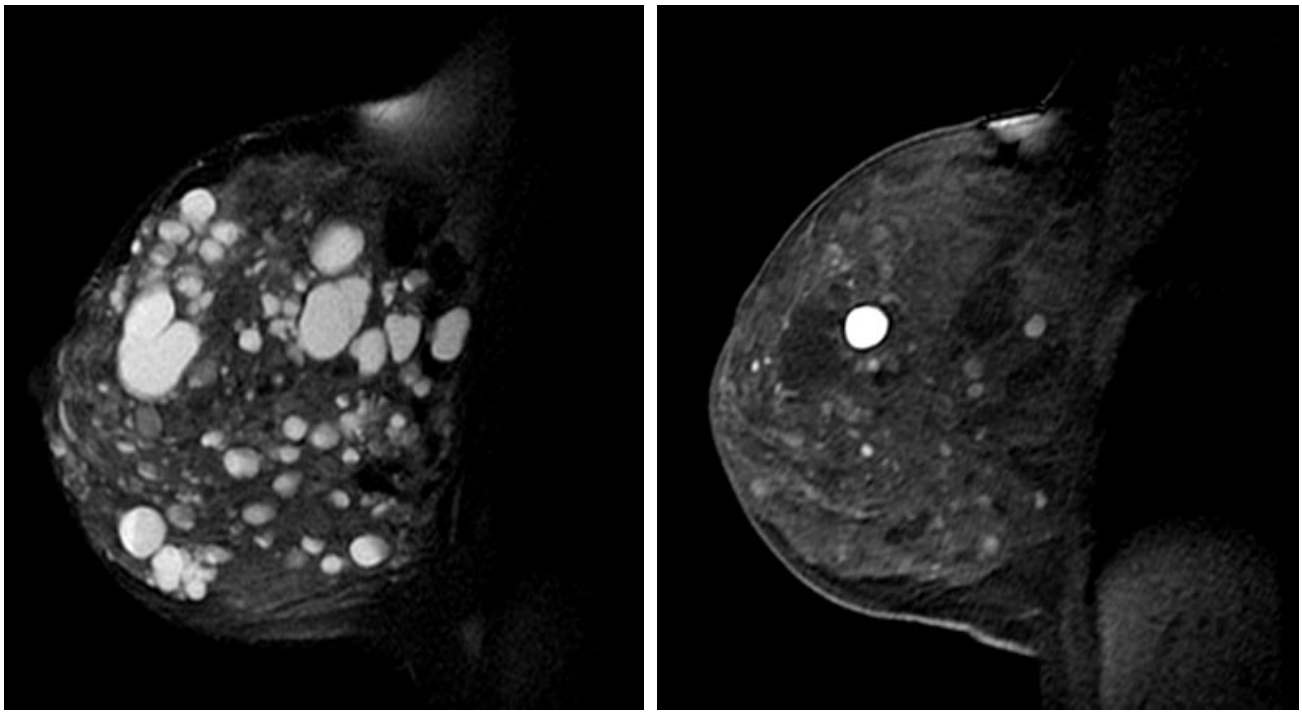


FIGURE 6.40. Abnormal signal void from a metallic clip placed during stereotactic biopsy. Note residual clumped enhancement around the clip indicating residual DCIS.



A B

FIGURE 6.41. Examples of cysts. (A) T2-weighted image demonstrating demonstrated numerous high signal cysts. (B) Precontrast T1-weighted image demonstrates several high signal cysts that have hemorrhagic or proteinaceous content.

6. Value of T2

False-positive biopsy results may be decreased by incorporating information from the T2-weighted images. Cysts, lymph nodes, and certain types of fibroadenomas (myxomatous) are high in signal on T2-weighted images. Although breast adenocarcinomas are generally not high in signal on T2-weighted images, mucinous carcinomas can exhibit high signal and enhance little. Similarly, necrotic tumors may exhibit high signal. However, if the lesion is high in signal on T2-weighted imaging it is more likely to be benign than malignant.

Cysts that are inflammatory and exhibit thin peripheral rim enhancement can be a diagnostic dilemma that is easily solved by referring to the T2-weighted images to confirm the presence of a high signal cyst. Similarly, kinetic uptake of contrast in lymph nodes can mimic breast cancer by exhibiting rapid uptake and early washout. However, if one is able to see a high signal mass on T2 that has morphology suggestive of a lymph node (smooth borders and reniform in shape) a biopsy may be avoided. High cellular fibroadenomas can also be confirmed by assessing the morphological pattern and confirming the high T2 signal.

7. Kinetics

Enhancement kinetics are particularly helpful if the lesion has a benign morphologic appearance. Any suspicious morphologic feature should prompt biopsy and kinetic analysis in these cases, while interesting, is not necessary, as the decision to biopsy has already been made. However, in the case of a well-defined mass that could quite possibly be benign, enhancement kinetic data may help one decide whether biopsy is required or whether it is safe to recommend follow up of the lesion.

To perform kinetic analysis, high temporal resolution is required so that multiple acquisitions can be obtained after the intravenous contrast bolus. In general, the time per sequential acquisition should be under 2min.

Kinetic techniques analyze the enhancement rate of a lesion by manually placing a region of interest (ROI) over the most intensely enhancing area of the lesion. The signal intensity in the region of interest is then plotted over time. Clearly, the more acquisitions obtained after intravenous contrast administration, the more points on the curve. Additionally, the faster the acquisition, the more potential information obtained about the curve. If multiple ROIs are placed, the most suspicious curve should be reported. The ROI size should be >3 pixels. Signal intensity (SI) increase is measured relative to the baseline signal intensity value.

Three general types of curves are noted that rely less on the absolute value of the enhancement than on the shape of the enhancement curve.[13,14] A type I curve is continuous enhancement increasing with time. A type II curve reaches a plateau phase where maximum signal intensity is reached approximately 2 to 3min after injection and the signal intensity remains constant at this level. Type III is a washout curve where there has been a decrease in signal intensity after peak enhancement has been reached within 2 to 3min.

Benign lesions follow a type I curve and malignant lesions follow a type III curve. A type II curve can be seen with both benign and malignant lesions. As with morphologic analysis, malignant lesions can exhibit benign kinetics and vice versa.

8. Suggested Algorithm for Interpretation

An approach to breast MRI interpretation is outlined here (Figure 6.42). Initial evaluation of T2-weighted images is performed to determine if high signal masses, such as cysts, lymph nodes, or myxoid fibroadenomas, are present. Evaluation of the nonenhanced T1-weighted images documents the presence of high signal hemorrhagic or proteinaceous cysts as well as high signal within dilated ducts. The postcontrast T1-weighted images demonstrate the presence of any enhancing masses or nonmass-like areas of enhancement. Morphologic analysis of the architectural features of a mass would then determine if the margins are irregular or spiculated, findings that would be highly suggestive of malignancy. At this point, biopsy would be recommended. A search for the mass by ultrasound may be helpful to allow percutaneous biopsy.

If the mass demonstrates smooth margins and rim enhancement, as rim enhancement is highly predictive of malignancy, biopsy would be recommended as well, once the false-positive causes of rim enhancement, such as inflamed cyst and fat necrosis, have been excluded. Simi-

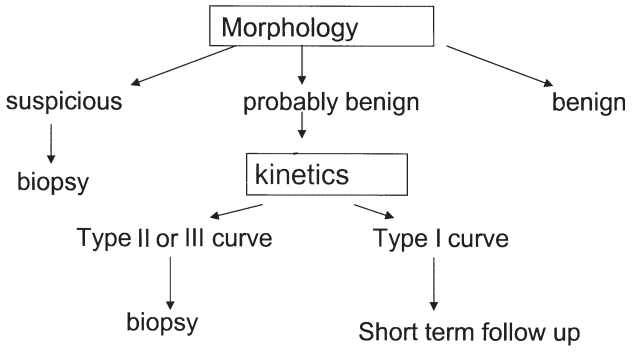


FIGURE 6.42. Algorithm for interpretation.

larly, ductal enhancement that is irregular or clumped will be suspicious for DCIS and biopsy will generally result from this finding.

If, however, the mass is homogeneously enhancing and demonstrates smooth borders, possibly representing a benign finding, kinetic analysis case can be extremely helpful. Kinetics can determine whether this is indeed likely benign (type I curve) or possibly malignant (type II or III curve), prompting biopsy. Because a homogeneously enhancing smooth mass with a type I or II curve has been reported in some malignant lesions, short-term follow up in 6 months may be advisable, if this combination of findings is found to document benignity.

For areas of nonmass-like enhancement, kinetic analysis may be helpful regional enhancement can be found in both benign and malignant breast pathology, such as proliferative changes and DCIS. Kinetic curves may have little use in stippled enhancement, as the tiny foci of enhancement are likely too small for accurate placement of an ROI.

8. Conclusion

The current definitive lexicon for breast MRI incorporates both morphologic and kinetic features of lesions identified on breast MRI. This chapter introduces this material and should not be used as a definitive breast MRI lexicon. It is hoped that terms and concepts presented here will serve as a template to which future lexicon terminology can be added.

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