Radiology of the Normal Breast and Overview of Breast Imaging Reporting and Data System

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Until breast cancer can be prevented, regular screening programs are widely recommended for asymptomatic women. The goal of breast cancer screening is early detection of disease, to be followed by appropriate treatment. Evaluating any screening program is challenging, and breast cancer screening has been subject to many controversies over the years. The many modalities that have been studied for possible inclusion in screening programs include screening mammography, ultrasound, and magnetic resonance imaging. Awareness of the breast anatomy is essential in order to generate an accurate differential diagnosis and guide patient management. Use of standardized terminology, report organization, and assessment structures allows radiologists to communicate breast imaging findings to referring physicians clearly and succinctly. The Breast Imaging Reporting and Data System (BI-RADS) lexicon was released by the American College of Radiology (ACR) with the goal of standardizing mammography reporting by providing a specific lexicon of imaging features. The purpose of this chapter is to review current knowledge of breast anatomy with a focus on relevant anatomy for diagnosis and intervention, and to provide a general overview of the BI-RADS lexicon.

2.1 Normal Anatomy of the Female Breast

Understanding breast anatomy and its appearance on imaging studies is important for several reasons. First, any interventionist would not want to mistake variations in normal anatomy for a pathologic disorder and possibly harm a patient with an intervention. Second, recognizing the location of abnormality in the breast, within the normal background anatomy, often narrows the list of possible diagnoses for the abnormality. Third, knowledge of breast anatomy enables safe approaches to breast intervention, especially to avoid interventional breast procedures complications (e.g., bleeding or pneumothorax) [1, 2].

The breast is a symmetrical organ located on the front of the chest on both sides of the midline. It occupies an area that stretches from the third to the seventh rib and from the edge of the sternum to the armpit. The volume, shape and degree of development are very variable in relation to various factors such as age, gland development, amount of fat and relative influence of endocrine stimulation [3].

At the center of the breast are the nipple and areola. The areola is a flat hyperpigmented area of skin with a round-to-oval

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shape and of variable diameter, usually between 3.5 and 6 cm. The nipple, at center of areola has a variable size and shape (conical, cylindrical). At its apex there are several small depressions that represent the outlets of the ducts. The areola surface is irregular due to the presence of the 8–12 tubercles of Morgagni, representing sebaceous glands (Fig. 2.1) [4].

The mammary gland is made of three components: glandular, adipose, and fibrous tissue (Fig. 2.2) [4]. The breast parenchyma is contained by a two-layer fold of the subcutaneous superficial fascia, that may be divided in two parts: (1) the superficial layer that covers the gland and contains fibrous septa, called Cooper's ligaments, which penetrate the gland and form the support structure of the parenchyma; and (2) the deep layer, which covers the posterior portion of the gland and separates it from the underlying superficial fascia of the pectoralis major muscle. Cooper's ligaments are the suspensory ligaments of the breast gland, and divide the parenchyma into lobes [3, 5].

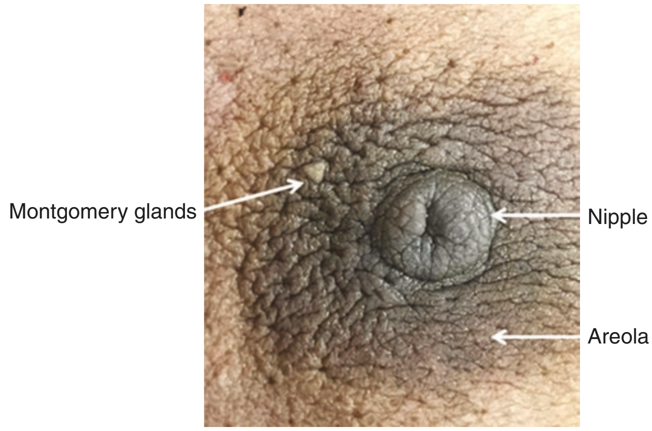


Fig. 2.1 Nipple-areolar complex (NAC). The NAC contains the montgomery glands, large intermediate-stage sebaceous glands that are embryologically transitional between sweat glands and mammary glands

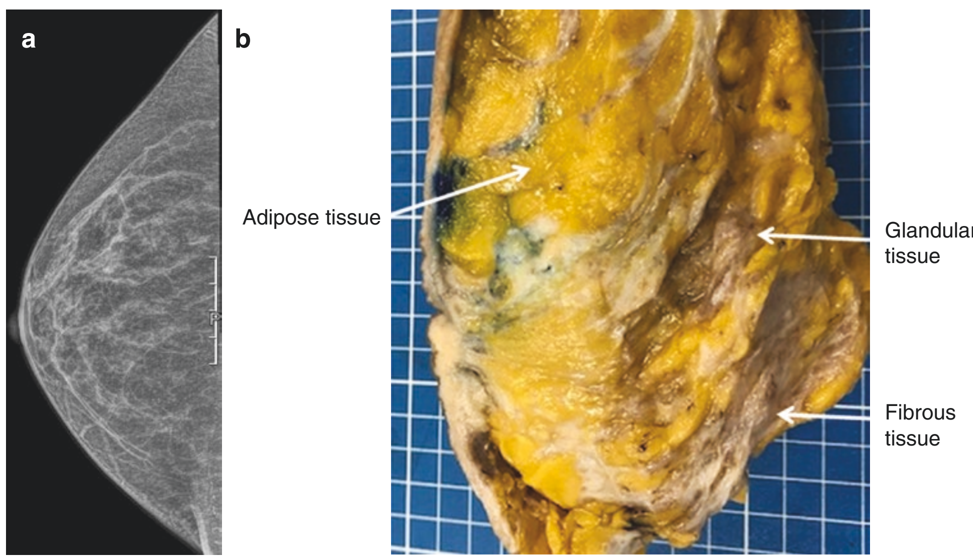


Fig. 2.2 Breast normal anatomy. (**a**, **b**) Mammary gland is made of three components: glandular, adipose, and fibrous tissue

2.2 Normal Mammographic Anatomy

The mammographic appearance of the normal breast depends of the amount of each of the main components: fat tissue appears radiolucent, while the stroma and the gland appear radiopaque. The sensitivity of mammography strongly depends on the density of the breast. A mammogram is usually performed in two projections, the MLO (medio-lateral-oblique) and CC (cranio-caudal) after compression [6].

The skin appears as a thin, continuous, radiopaque rim of homogeneous density of about 1 mm, and is readily distinguishable from the radiolucency of the underlying subcutaneous fat tissue. The areola usually has a thickness of 3–5 mm, with a central opacity of cylindrical shape corresponding to the nipple. Posteriorly there is the retroareolar region, a triangular-shaped area that is of particular interest because it may hide focal anomalies such as breast tumors (Fig. 2.3) [7].

The subcutaneous fat appears as a thick radiolucent layer, crossed by fibrous linear structures that correspond to the crest of Duret and Cooper's ligaments. Behind the breast gland the fat tissue outlines the retromammary space, which separates the breast from the pre-pectoral fascia overlying the pectoralis major muscle (Fig. 2.4) [8].

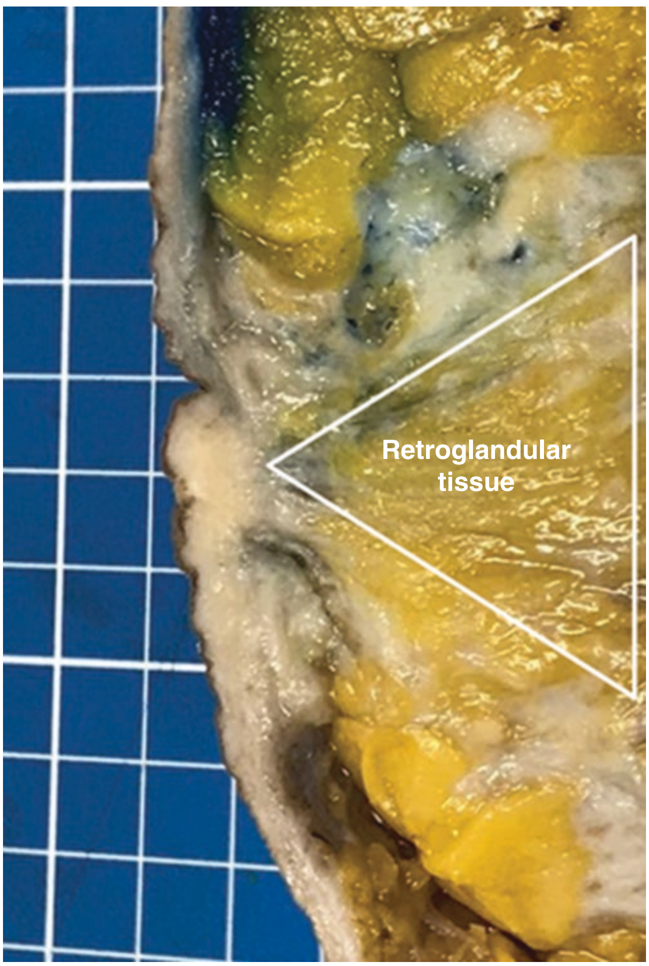


Fig. 2.3 Retroareolar region. Triangular-shaped area that may hide focal anomalies

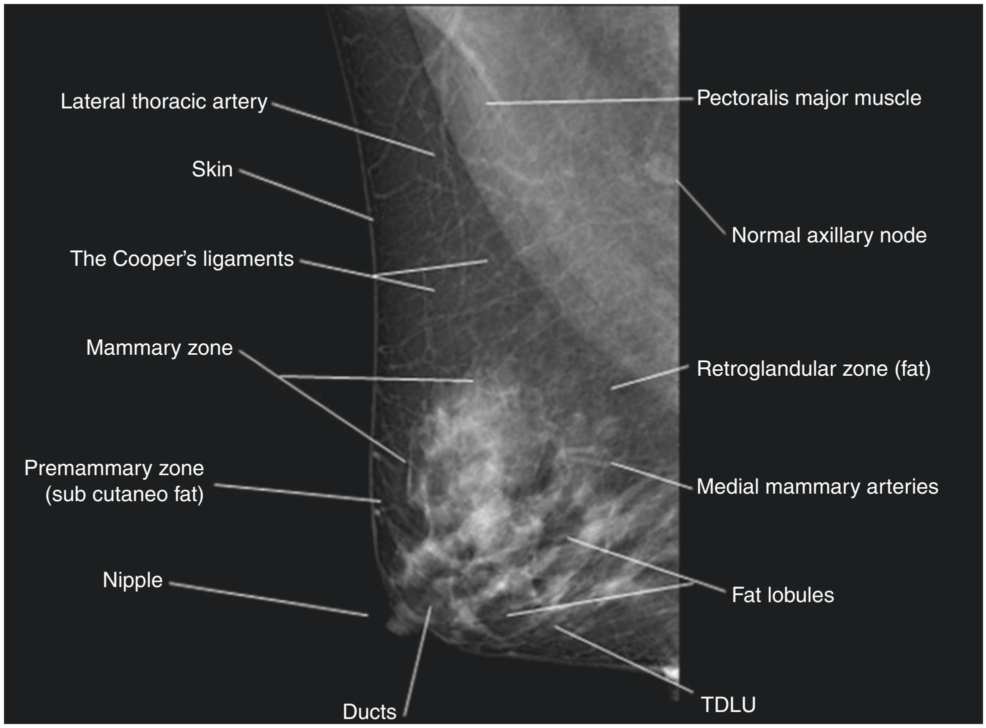


Fig. 2.4 Normal mammographic anatomy

2.3 Normal Ultrasonographic Anatomy

The normal breast as observed with ultrasound presents the skin line, the fibroglandular tissue (also known as the mammary gland), and the pectoralis muscle as hyperechoic (maximum sound reflection and little sound transmission) and the subcutaneous fat and retromammary fat are visualized as hypoechoic, which is to say that they bounce back only a small amount of sound and allow maximum transmission through them (Fig. 2.5) [9].

The course of the ducts imaged by ultrasound from the nipple into the breast is diverse and complicated. The central ducts do not extend in a radial fashion from the nipple toward the chest wall, whereas the peripheral ducts drape over the central ducts in a radial fashion. (Fig. 2.6). The breast has alternate hyperechoic and hypoechoic layers as follows [10, 11]:

1. Skin-hyperechoic
2. Subcutaneous fat-hypoechoic
3. Fibroglandular parenchyma-hyperechoic
4. Retromammary fat-hypoechoic
5. Muscle, mainly the pectoralis major-hyperechoic

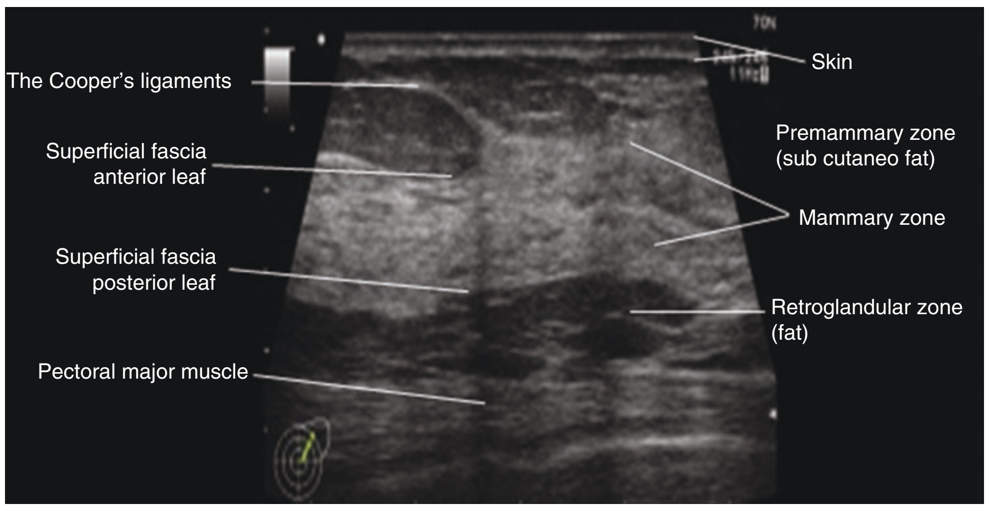


Fig. 2.5 Normal ultrasound anatomy

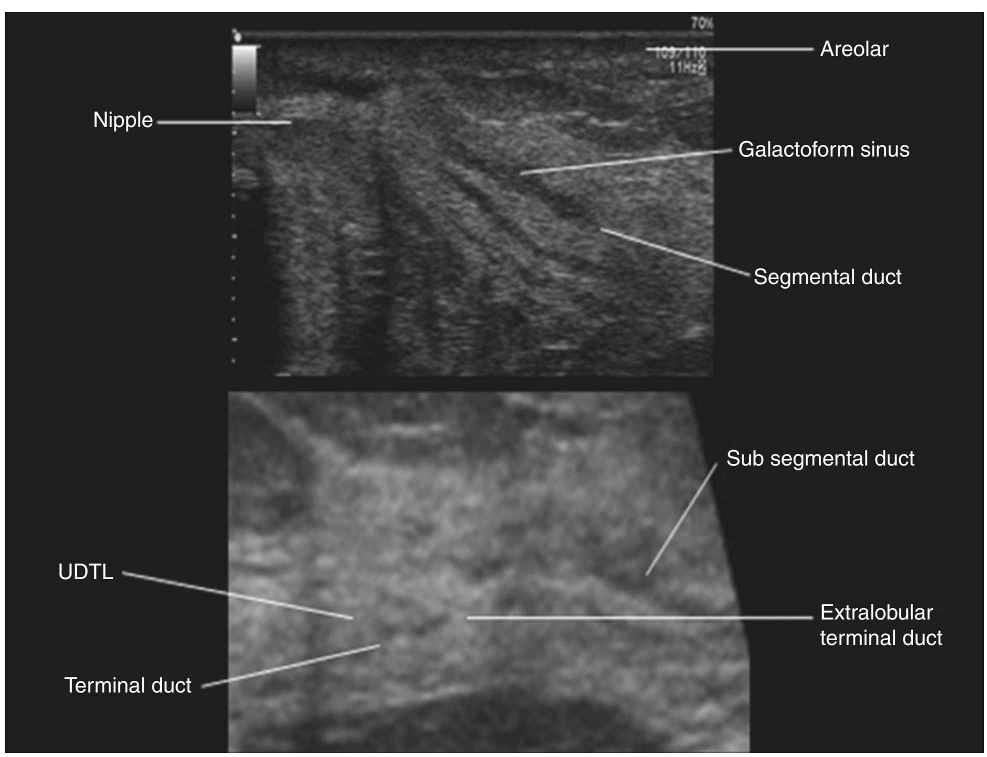


Fig. 2.6 Normal ultrasound anatomy of breast ducts

2.4 Magnetic Resonance (MR), Normal Anatomy

Normal anatomic components of the breast can be visualized and distinguished on MR imaging by assessing signal intensity. On T1-weighted imaging without fat saturation, adipose tissue is of high signal intensity and breast fibroglandular elements appear relatively intermediate-to-dark [12]. The presence of fat can be confirmed by assessing the same region on T1-weighted images with fat saturation, where adipose signal would be expected to be nulled. In T1-weighted images with fat saturation, the relative signal intensity of fibroglandular elements then becomes intermediate-to-bright, given that the fat appears dark. Similarly, on T2-weighted series with fat saturation, fat appears dark while breast parenchyma appears intermediate to bright (Fig. 2.7) [13].

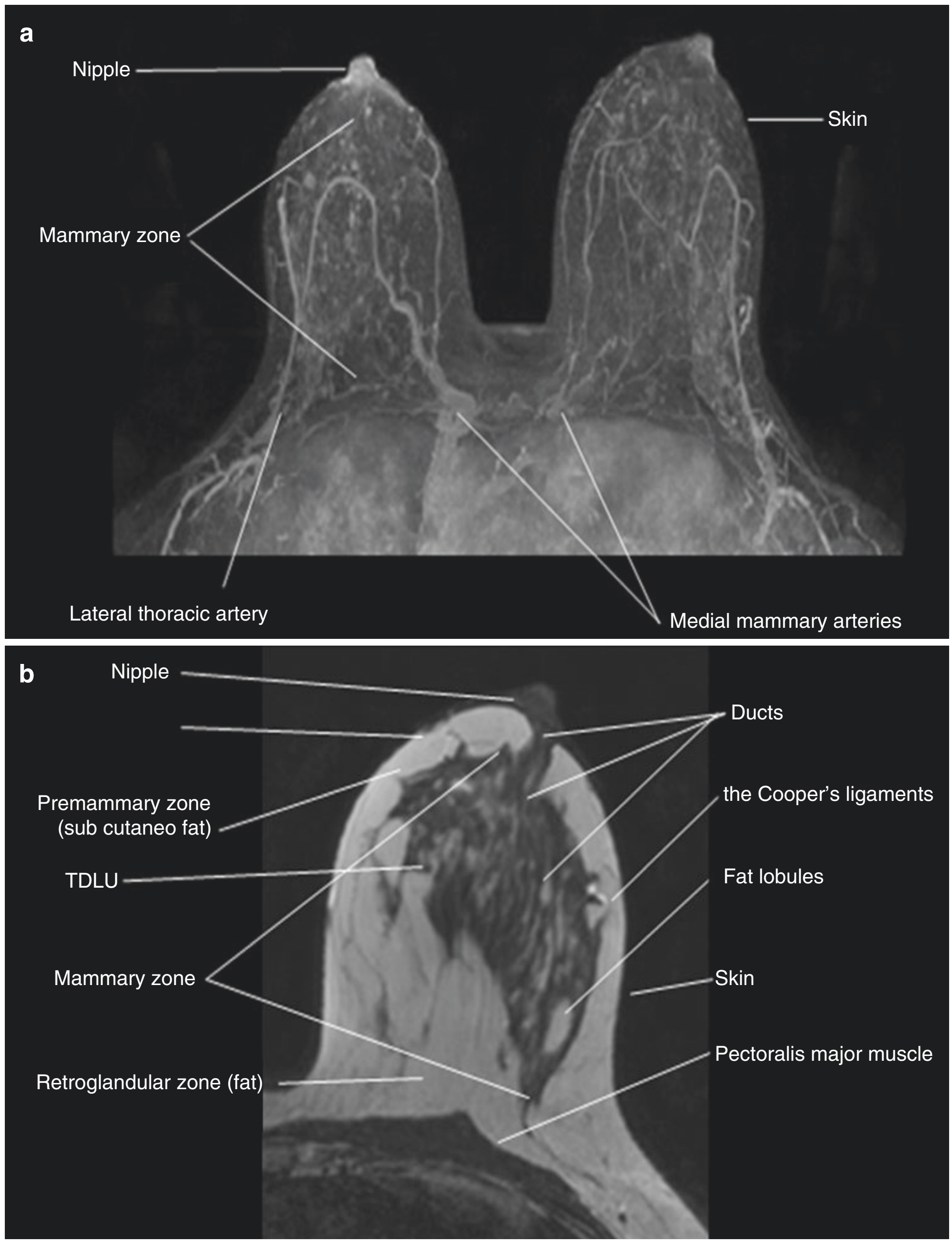


Fig. 2.7 (**a**, **b**) Breast magnetic resonance: normal anatomy

2.5 Breast Imaging Reporting and Data System (BI-RADS) Lexicon Fifth Edition (2013)

Before the development of the BI-RADS lexicon, mammography reports contained ambiguous and often unintelligible descriptions that made clinical management difficult for referring physicians. The first edition of the BI-RADS lexicon was released by the American College of Radiology (ACR) in 1993, with the goal of standardizing mammography reporting by providing a specific lexicon of imaging features. Lexicon descriptors were designed to predict both benign and malignant disease, eliminate ambiguity, allow automated data collection, and facilitate communication with referring physicians. Structured reports were organized into several categories, including breast density, description of findings, and a final decision-oriented assessment. Revisions were made in 1995, 1998 (the addition of an imaging atlas with examples of each descriptor), 2003 (revised terminology, subdivided category 4 findings, and introduction of US and MR imaging standardization) [14], and 2013. Use of the BI-RADS lexicon now facilitates quality assurance, communication, research, and improved care [15].

2.5.1 Density

In the BI-RADS edition of 2003, the assignment of the breast composition was based on the overall density resulting in ACR category 1 (<25% fibroglandular tissue), category 2 (25–50%), category 3 (51–75%), and category 4 (>75%). In the BI-RADS edition of 2013, the use of percentage is discouraged, because in individual cases it is more important to take into greater account the chance that a mass can be obscured by fibroglandular tissue than the percentage of breast density as an indicator for breast cancer risk. The assignment of breast composition is changed into categories *a*, *b*, *c*, and *d*, each followed by a description:

(a) The breasts are almost entirely fatty (Fig. 2.8)
(b) There are scattered areas of fibroglandular density
(c) The breasts are heterogeneously dense, which may obscure small masses
(d) The breasts are extremely dense, which lowers the sensitivity of mammography (Fig. 2.9)

Fig. 2.8 Breast composition (fibroglandular tissue within the breast). ACR category *a*. (**a**) Mammography. (**b**) Gross aspect of a breast almost entirely fat

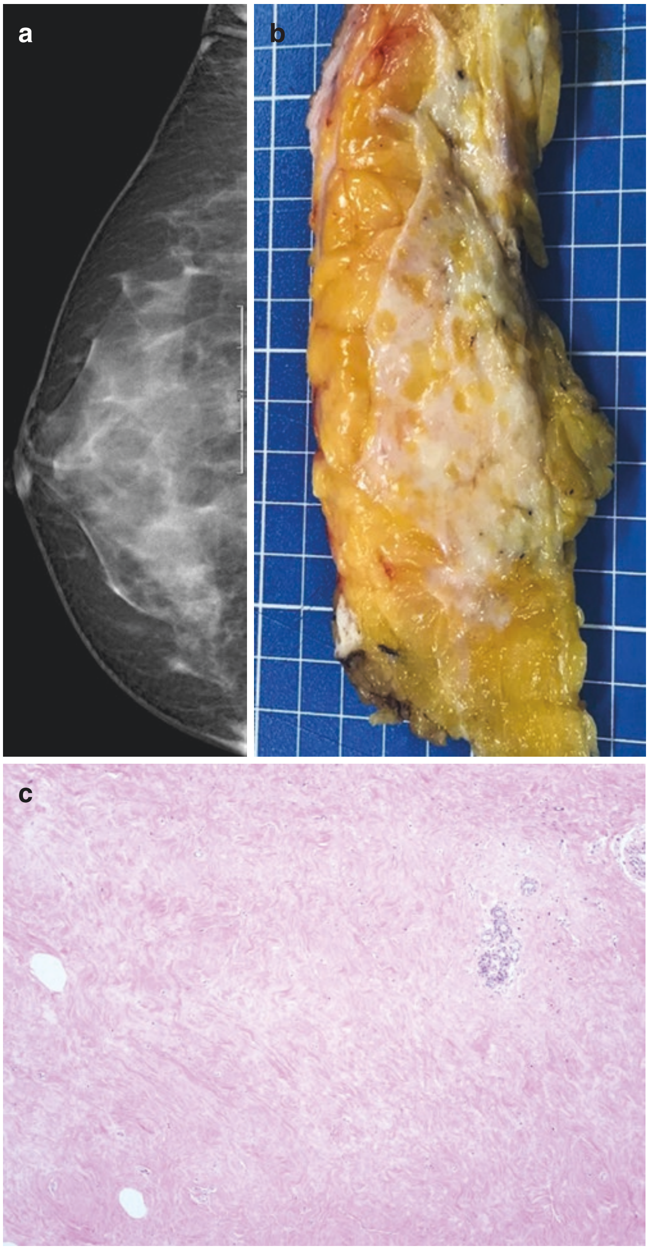


Fig. 2.9 The breast is extremely dense. Breast composition category *d*. (**a**) Mammography, the breast is dense, which may obscure small masses. (**b**, **c**) Gross and microscopic features of a dense fibroglandular tissue

2.5.2 Assessment

All final assessments (BI-RADS categories 1, 2, 3, 4, 5, and 6) should be based on thorough evaluation of the mammographic features of concern or after determination that an examination is negative or benign (Table 2.1).

An incomplete (category 0) assessment is usually given for screening examinations when additional imaging evaluation is recommended before it is appropriate to render a final assessment. There may be rare situations in the screening setting in which a category 4 or 5 assessment is used, but this practice is discouraged because it may compromise some aspects of outcome analysis [15].

A recall (category 0) assessment should include specific suggestions for the next course of action (spot-compression magnifications views, US, etc.) [16].

Table 2.1 BI-RADS assessment categories

Category	Assessment
0	Incomplete-need additional imaging evaluation and/or prior mammograms for comparison
1	Negative
2	Benign
3	Probably benign
4	Suspicious
4A	Low suspicion for malignancy
4B	Moderate suspicion for malignancy
4C	High suspicion for malignancy
5	Highly suggestive of malignancy
6	Known biopsy–proven malignancy

2.5.3 Masses

Mass shapes are reduced to three categories in the fifth edition: oval, round, and irregular (Fig. 2.10). The term lobular has been eliminated and absorbed into the term round or oval or, if there are more than two or three gentle lobulations, the term irregular [17].

Margin categorization is unchanged, with five categories described; circumscribed, obscured, microlobulated, indistinct, and spiculated. The majority of masses with circumscribed margins are benign, such as fibroadenomas (Fig. 2.11), and about 95% of the spiculated masses (Fig. 2.12) or microlobulated masses (Fig. 2.13) are malignant.

It is advisable to perform a targeted breast ultrasonogram (USG) whenever there is a palpable or focal mammographic abnormality in the breast. Although USG is not efficacious as a screening modality, combined mammography and USG pick up more cancer than mammography alone [18]. Fibroadenoma is usually homogeneous, well-circumscribed, hypoechoic, ellipsoid, wider than tall, and may even show posterior enhancement on USG (Fig. 2.14), and intracystic or intraductal papillomas show a complex cyst (Fig. 2.15).

Simple cysts in the breast are completely anechoic, with a thin echogenic capsule, posterior enhancement, and thin edge shadowing (Fig. 2.16).

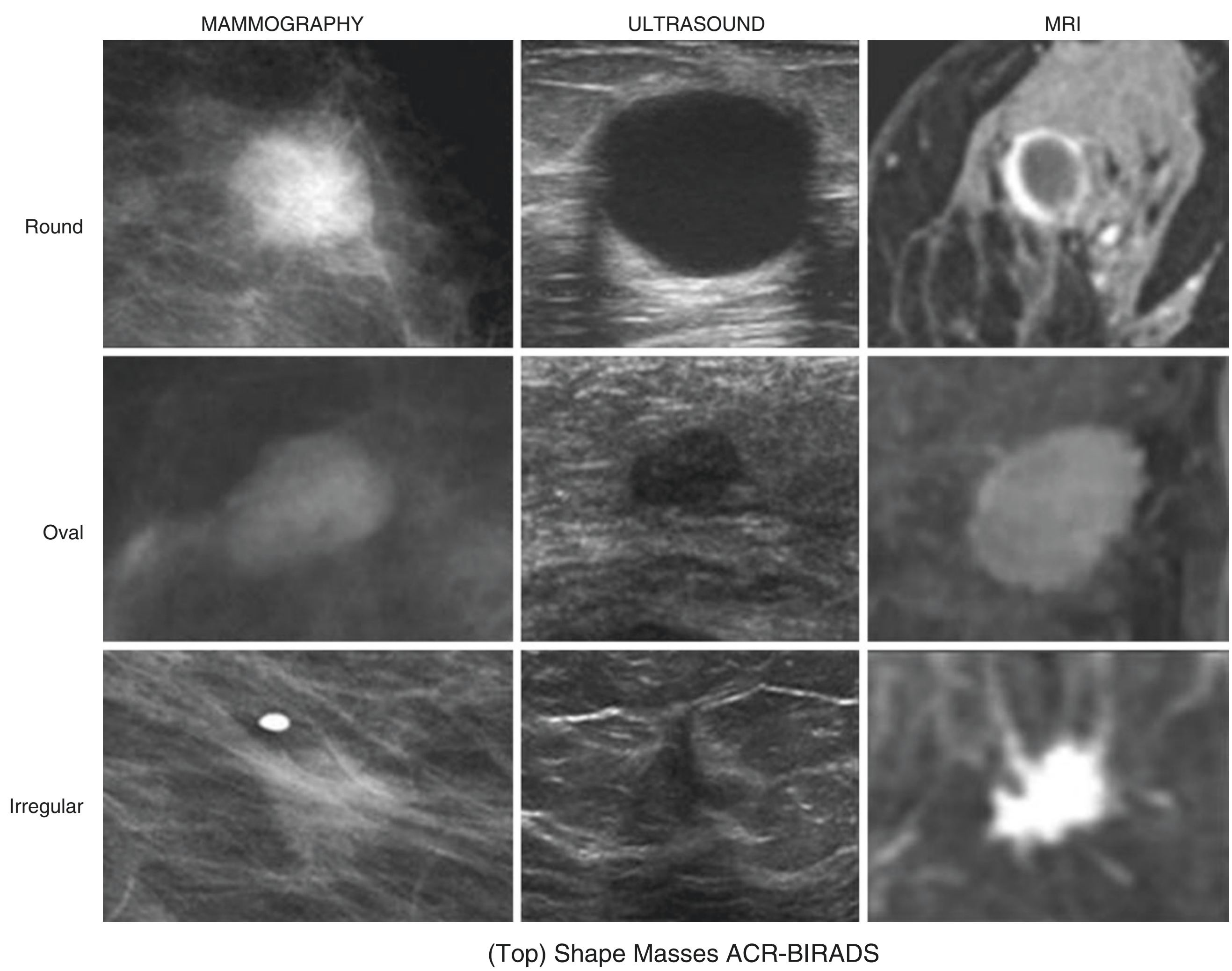


Fig. 2.10 BI-RADS margins. Radiologists describe masses according to both overall shape and margins. Digital zoom projection images show round, oval, and irregular masses (left to right: breast mammography, ultrasound, and magnetic resonance imaging)

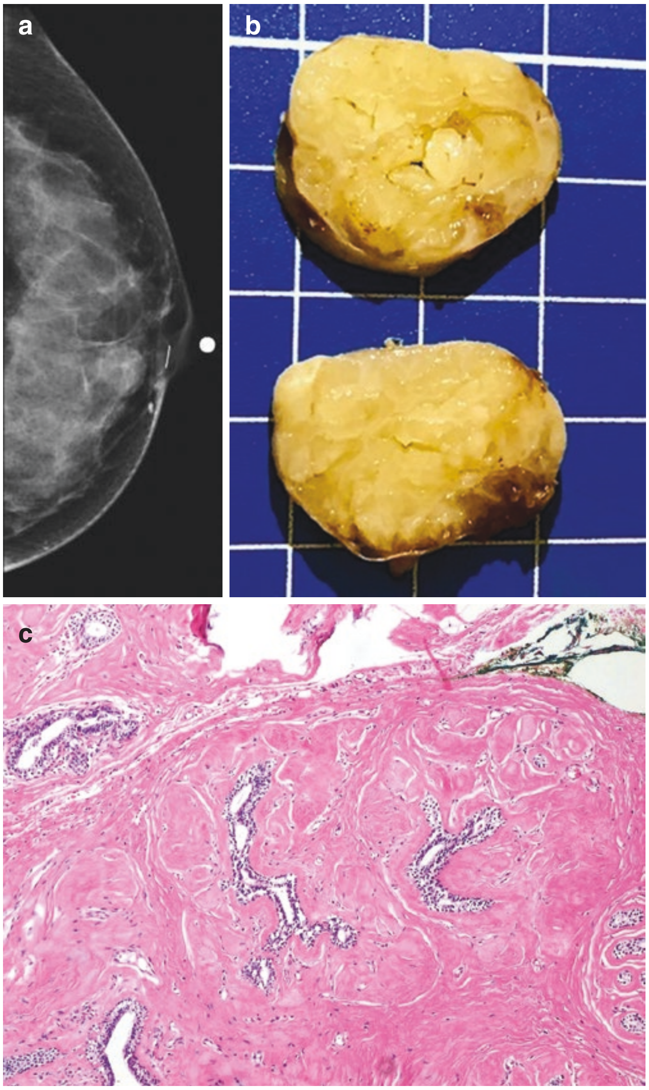


Fig. 2.11 Circumscribed margins. (**a**) CC mammography shows a round mass with well-circumscribed margins. (**b**) Gross: the lesion has a smooth rounded outline with a suggestion of a lobulated structure. (**c**) Fibroadenoma showing demarcation from the surrounding compressed breast tissue

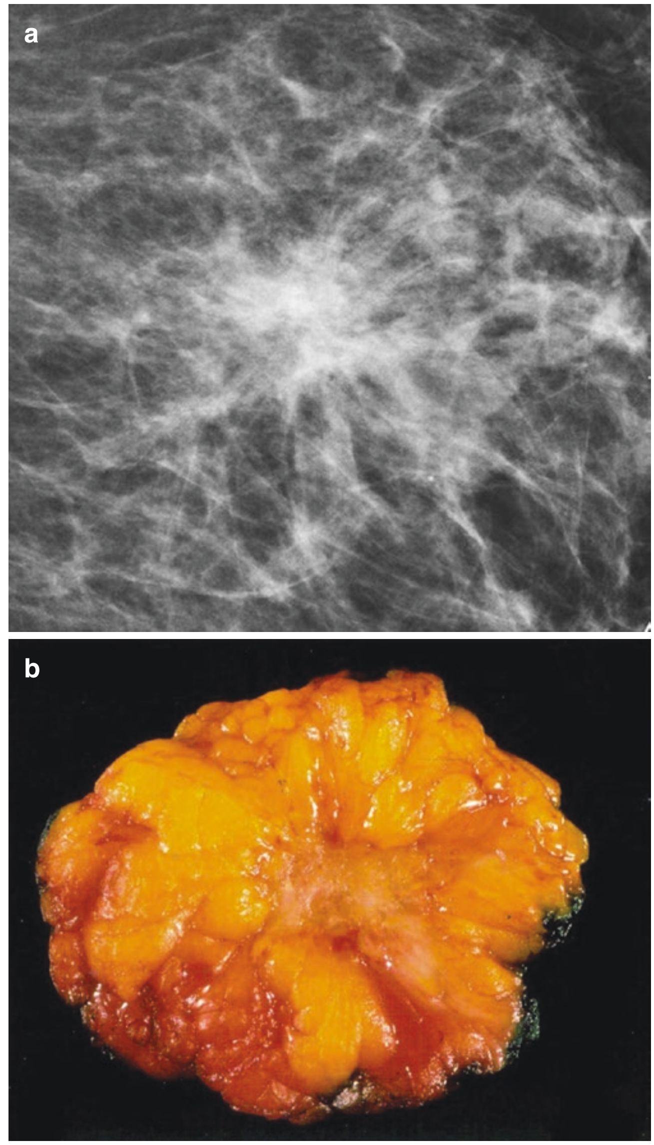
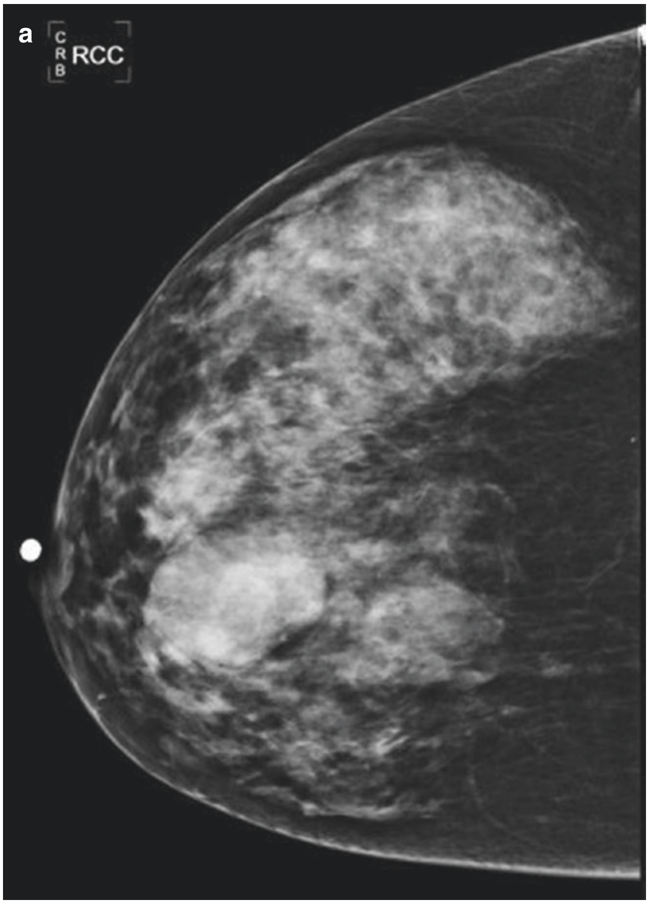


Fig. 2.12 Spiculated margins. (**a**) Mammography shows a mass with spiculated margins. (**b**) Invasive ductal carcinoma not otherwise specified (NOS), gross appearance of breast resection specimen with spiculated lesion



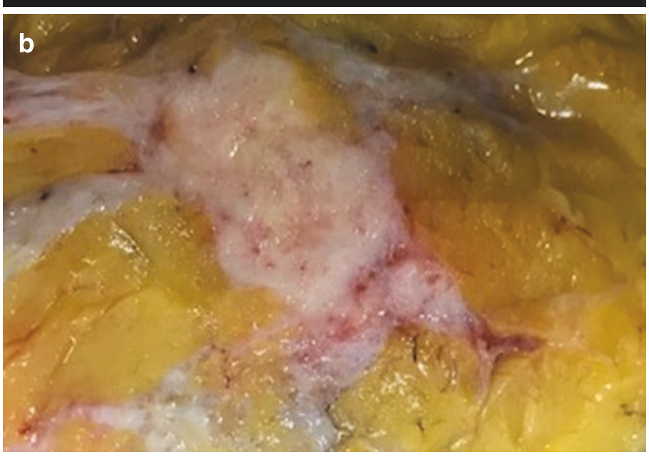


Fig. 2.13 Circumscribed margins. (**a**) Mammography shows circumscribed microlobulated mass. (**b**) Gross aspect of the specimen with a lobulated tumor. US guided biopsy confirmed Invasive Ductal Carcinoma NOS

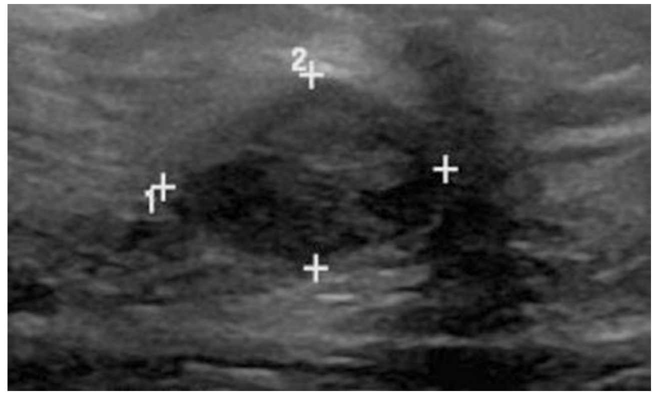


Fig. 2.14 Fibroadenoma. Breast USG shows homogeneous, hypoechoic, gently lobulated lesion suggestive of a fibroadenoma

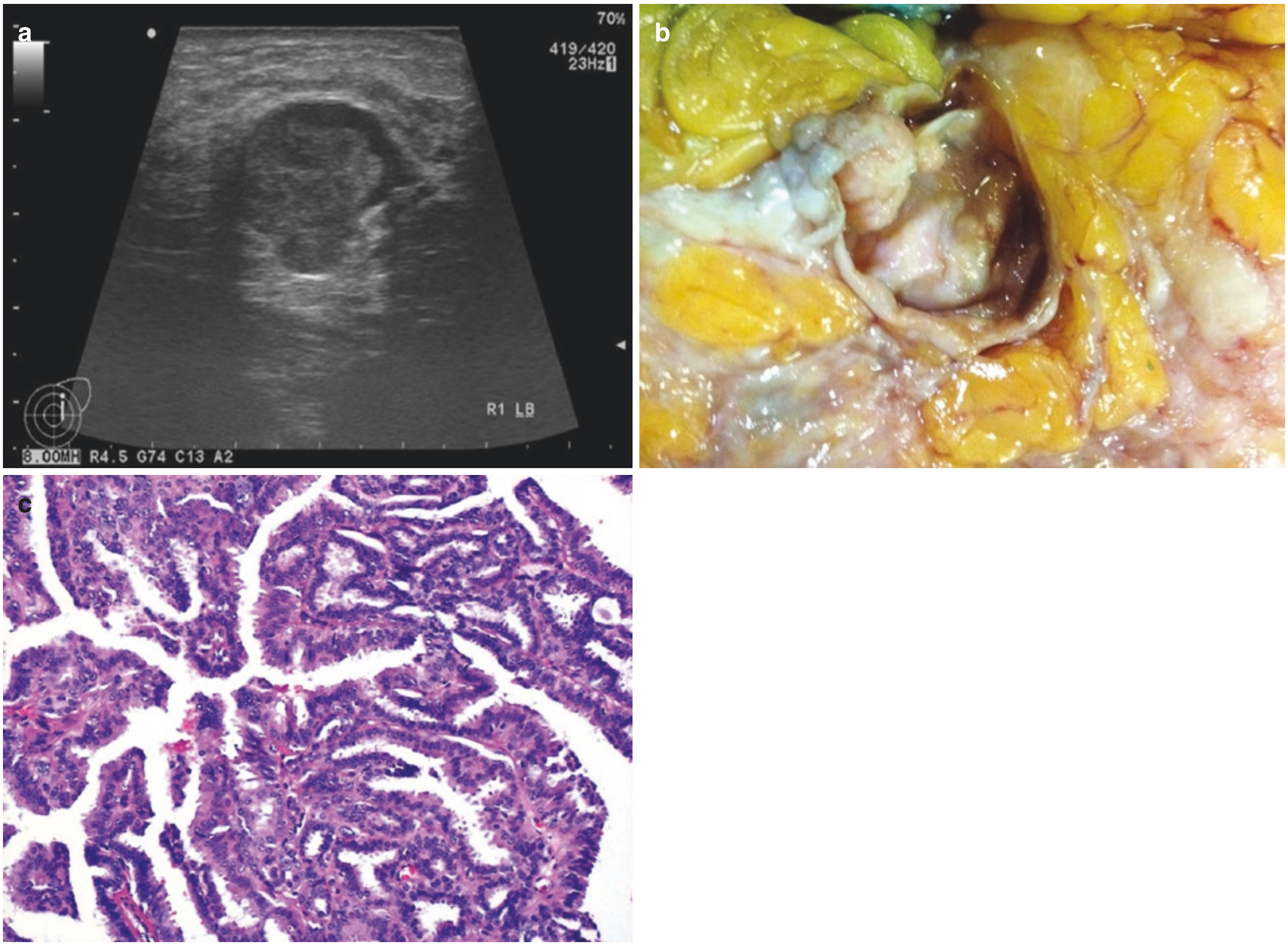


Fig. 2.15 Intraductal papilloma. (**a**) Breast US shows a complex cyst. (**b**) Large duct with an intraductal mass. (**c**) A benign intraductal papilloma with arborescent papillary fronds and well developed fibrovascular cores

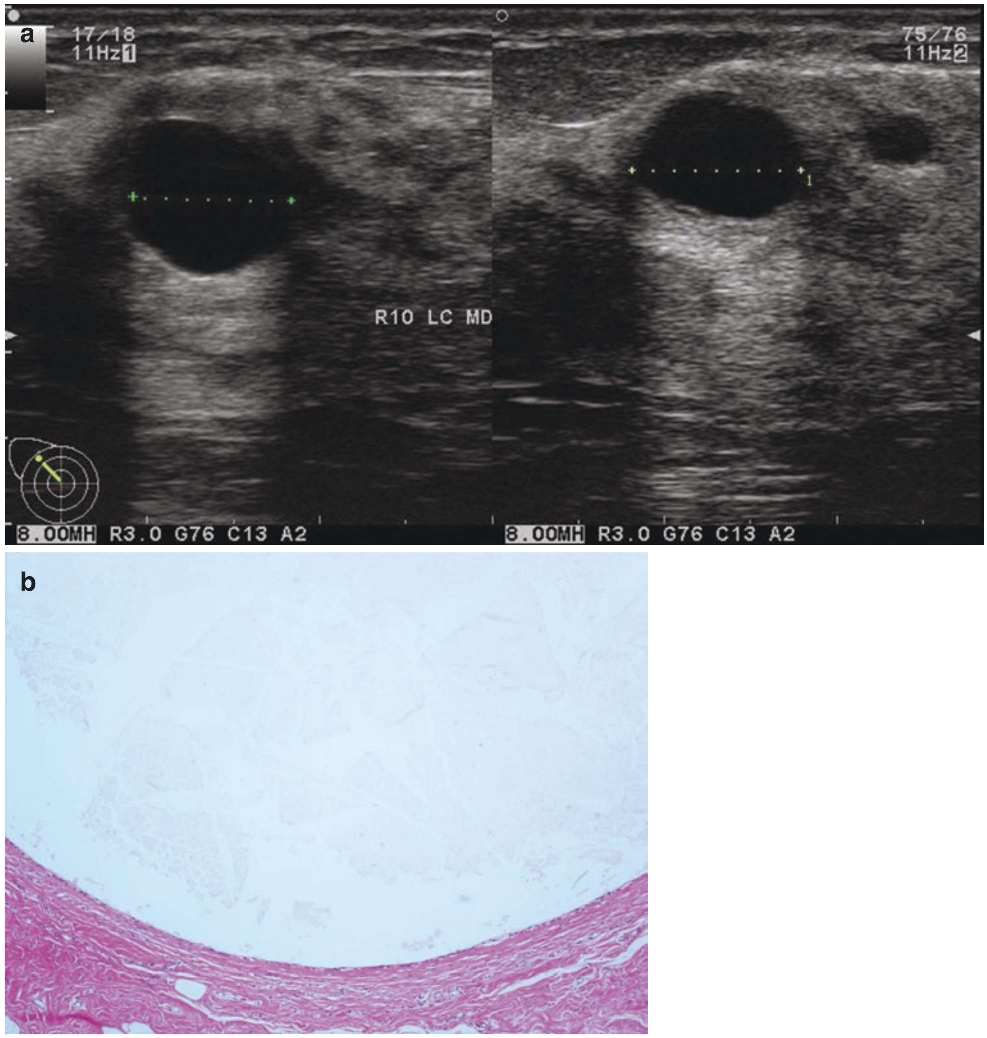


Fig. 2.16 Circumscribed margins. (**a**) Ultrasound shows an anechoic imperceptible wall. (**b**) Excisional biopsy shows a simple cyst

2.5.4 Calcifications

The previous BI-RADS mammography lexicon used the terms "grouped or clustered" for calcifications less than 1 cc in volume, and the term "regional" for calcifications greater than 2 cc. These terms did not address the group of calcifications measuring 1–2 cc in volume. The new edition has resolved this inconsistency by expanding the definition of "grouped" to a volume extending up to 2 cc. In addition, the terms "group or clustered," which could be used interchangeably with the previous BI-RADS edition, are being phased out and have been changed to the term "grouped" (historically clustered). The ultimate intention is to change it to "grouped" in a later revision [19].

Calcifications are now consolidated into two categories: (1) benign (Fig. 2.17); and (2) suspicious morphology. Amorphous, coarse heterogeneous, and fine linear branching calcifications are now placed in the "suspicious morphology" category (Fig. 2.18).

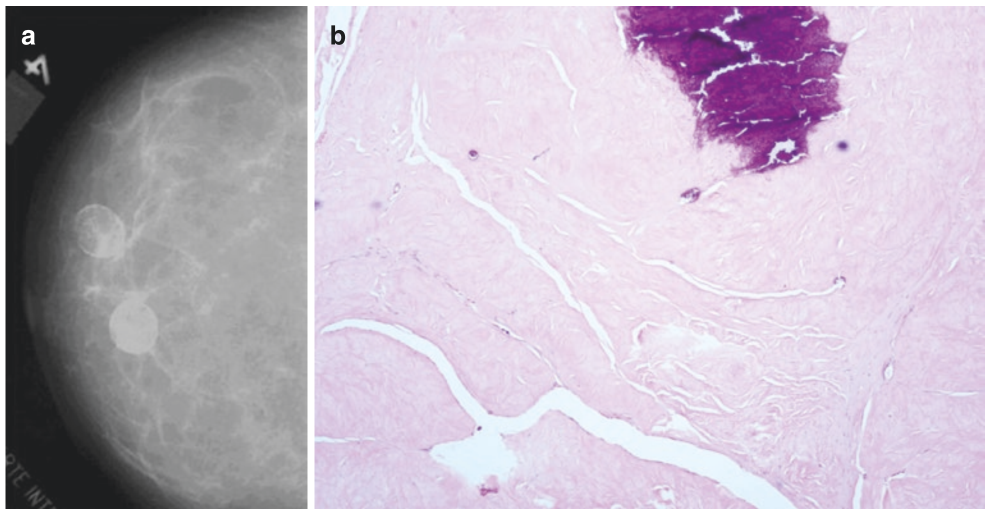


Fig. 2.17 Calcifications. (**a**) Calcifications surrounding a circumscribed lucent mas (Egg-shell). (**b**) Excisional biopsy (same patient) shows a fibroadenoma with macrocalcifications

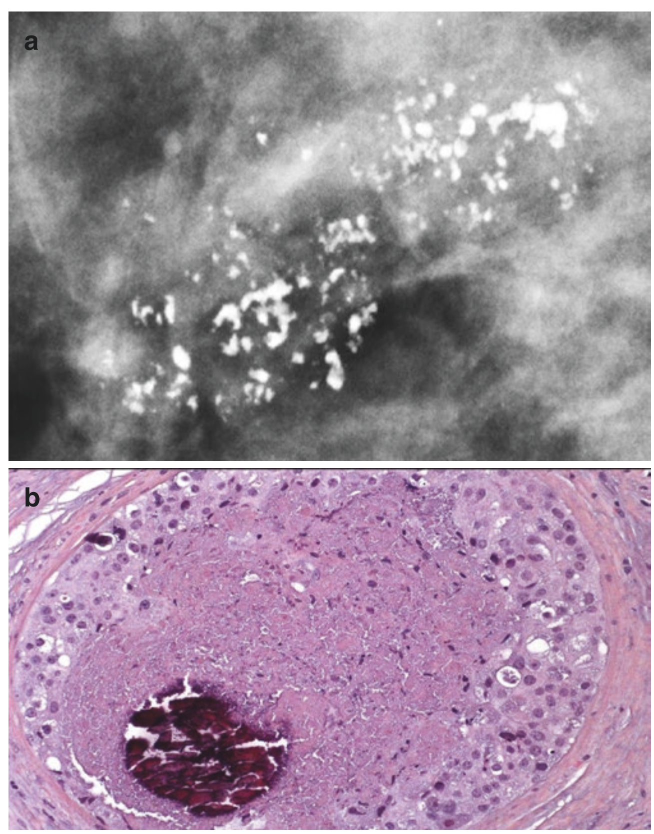


Fig. 2.18 Calcifications. (**a**) Mammography shows coarse heterogeneous calcifications. (**b**) Biopsy showed a high-grade ductal carcinoma in situ with comedo type necrosis

2.5.5 Architectural Distortion

Architectural distortion is the alteration of the normal breast architecture with thin spiculations radiating from a point without a definitive mass; focal retraction or distortion may be seen at the parenchyma margin. It can be a primary finding associated with a mass, asymmetry, or calcifications [2, 9].

The term architectural distortion (Fig. 2.19) is unchanged in the fifth edition.

2.5.6 Asymmetries

There are some descriptive terms in the updated BI-RADS that have been expanded, such as the terms that describe an "asymmetry," which often represents summation artifacts. In addition, a new term, "developing asymmetry," which describes a focal asymmetry that is new, growing, or more conspicuous, has been added to the existing types of asymmetries in the mammography lexicon [14, 15].

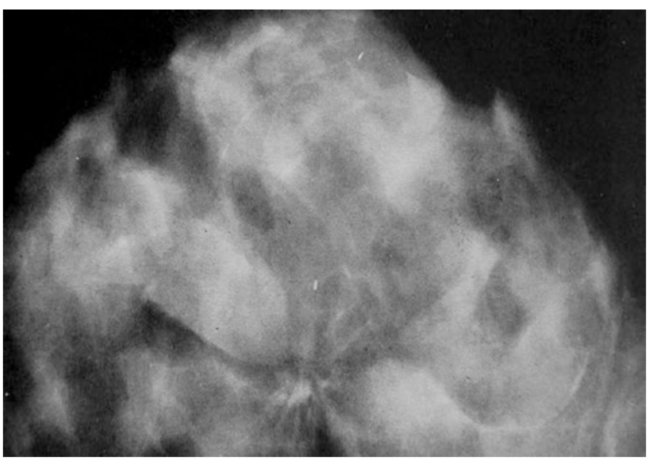


Fig. 2.19 Mammography of a palpable thickening shows an area of architectural distortion

2.5.7 Lesion Location

The new BI-RADS also provides clarification of terms used to describe lesion location on mammography. Previously, in cases where a lesion was located in the central breast or at the 12 o'clock location, a specific quadrant could not be assigned. The new BI-RADS has expanded the terminology for lesion location by adding terms such as "upper/lower/outer/inner central." This terminology allows for direct correlation of lesion location on ultrasound and MRI. Increased clarification has also been provided to describe the use of subcategories for the BI-RADS assessment Category 4. The new BI-RADS provides specific PPV cut-off points for BI-RADS 4A/4B/4C, which match certain specific imaging findings [15].

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