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Breast Anatomy for the Interventionalist

Robert A. Jesinger, MD, MSE^{*,†}

Normal breast anatomy can be seen on a variety of imaging modalities. Knowledge of normal breast anatomy on imaging examinations is important for an interventionalist, primarily to avoid mistaking normal anatomy for a pathologic disorder, so as not to harm a patient with an unnecessary intervention. Knowledge of breast anatomy is also critical in planning safe breast interventions and unwanted procedural complications. The key anatomical structures in the breast include skin, fat, fascial layers, Cooper ligaments, fibroglandular tissue, lymphatics, and neurovascular structures, all positioned over the chest wall. In men, the breast parenchyma is usually only composed of fat, with absence of fibroglandular tissue. In women, fibroglandular tissue volumes vary with age, with many women having a predominance of fat within the breasts after menopause. Embryologically, the breast develops under genetic and hormonal influence from skin precursor cells during the fourth through twelfth weeks of gestation, and the resulting breast bud continues to lengthen and branch throughout the remainder of gestation, forming a complex network of radially arranged breast ducts that connect the nipple with the mammary lobules. The key arterial blood supply to the breast arises from the internal thoracic artery, but additional arterial blood supply is seen from intercostal and lateral thoracic arteries. The venous anatomy and lymphatic drainage of the breast generally parallels the arterial anatomy, with presence of variation in communicating channels between deep and superficial venous and lymphatic channels. Tools that assess breast vascular structures (eg, contrast-enhanced breast magnetic resonance imaging) and lymphatic structures (nuclear medicine lymphoscintigraphy) are routinely used to assess extent of breast disease and help guide breast interventions.

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Introduction

Understanding breast anatomy and its appearance on imaging studies is important for several reasons. First, any interventionalist 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 an abnormality in the breast, within the normal background anatomy, often narrows the list of possible diagnoses for the abnormality. As radiologic-

pathologic correlation is frequently used after a breast intervention (eg, multidisciplinary breast conference discussion of a breast biopsy), discordance between the pathologic diagnosis from tissue or fluid samples obtained and clinical or imaging diagnosis must be reviewed and clarified for appropriate patient care. Third, safe approaches to breast intervention require knowledge of breast anatomy, especially to avoid interventional breast procedure complications (eg, bleeding and pneumothorax). This article reviews our current knowledge of breast anatomy with a focus on relevant anatomy for diagnosis and intervention.

Breast Embryology

The human breast develops under genetic and hormonal influence from skin precursor cells (ectoderm) during the fourth week of embryonic life.¹ Ectodermal thickenings

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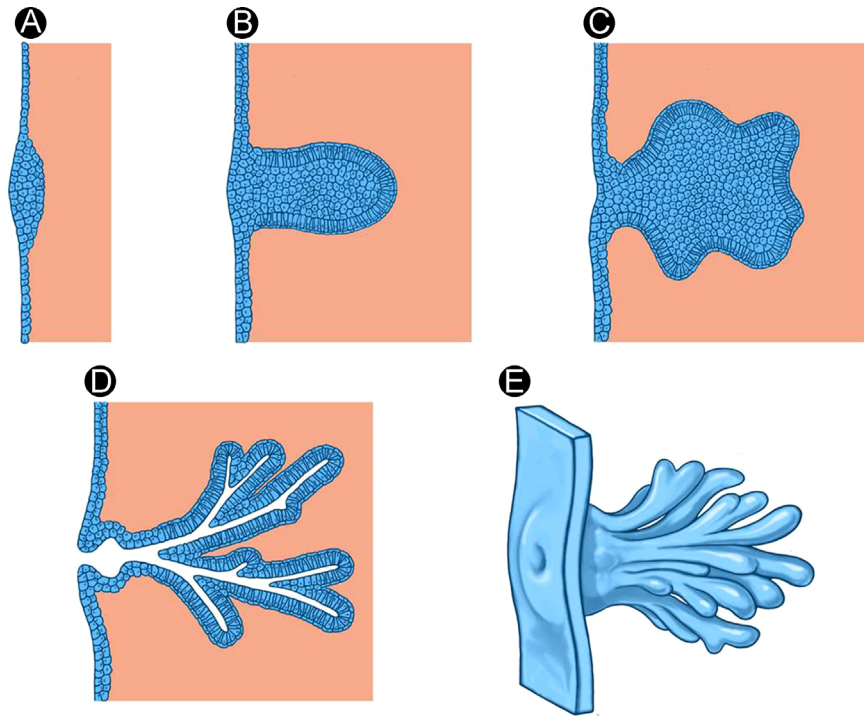


Figure 1 The normal embryologic development of the breast. (A) Mammary bud as seen during the fifth week of gestation. (B) Growth of mammary bud downward into the chest beyond the fifth week of gestation. (C) Formation of secondary buds between the fifth and twelfth weeks of gestation. (D) Formation of mammary lobules by the twelfth week of gestation. (E) Continued growth of mammary lobules beyond the twelfth week of gestation, with lengthening and branching of ducts into a complex network of radially arranged breast ducts that connect the developing (inverted) nipple. (Color version of figure is available online.)

(termed mammary ridges) evolve in humans on the chest at the level of the fourth intercostal space and form a mammary bud by the fifth week of gestation (Fig. 1A). From the fifth through the twelfth weeks of gestation, the primary mammary bud grows downward into the chest, forming secondary buds and mammary lobules (Fig. 1B-D). Background breast stroma (fat, ligaments, nerves, arteries, veins, and lymphatics) develops throughout gestation. Beyond the twelfth week of gestation, the secondary buds continue to lengthen and branch, forming a complex network of radially arranged breast ducts that connect the developing (inverted) nipple with the growing mammary lobules (Fig. 1E). The nipple usually everts after birth owing to proliferation of lubricating sebaceous glands (of Montgomery) and the development of erectile tissue, while the surrounding areola increases in pigmentation. Failure of nipple eversion can occur, is often hereditary, and is usually secondary to fibrous tethering of the nipple within a hypoplastic ductal system. After cessation of maternal hormone effects after birth, the breasts become quiescent until the onset of puberty.

With the onset of puberty, breast enlargement varies between male and female breasts. In the peripubertal period, the male breast experiences androgenic antagonistic effects on ductal and stromal growth, as compared with the proliferative effect on the female ducts and stroma by estrogen. As a result, fat makes up most of the breast volume in men, with few residual ducts and stromal

elements owing to involution and atrophy (Fig. 2). In the female breast, puberty increases circulating estrogen,

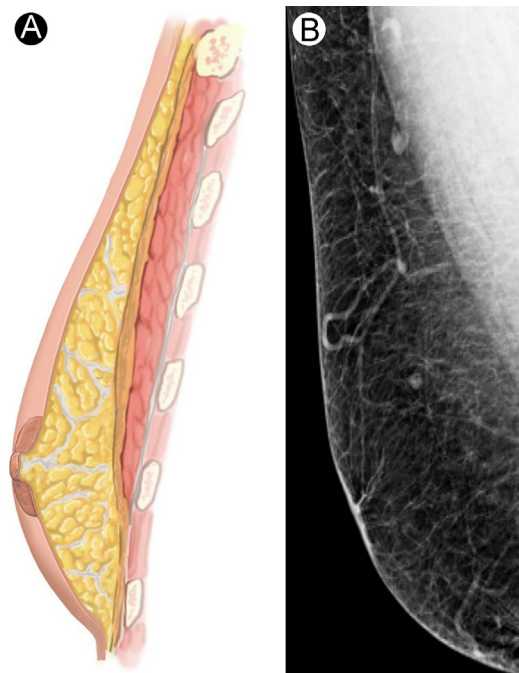


Figure 2 Normal male breast anatomy. (A) Illustration of the male breast in vertical cross section. (B) Medial lateral oblique (MLO) mammographic view of the normal male breast. (Color version of figure is available online.)

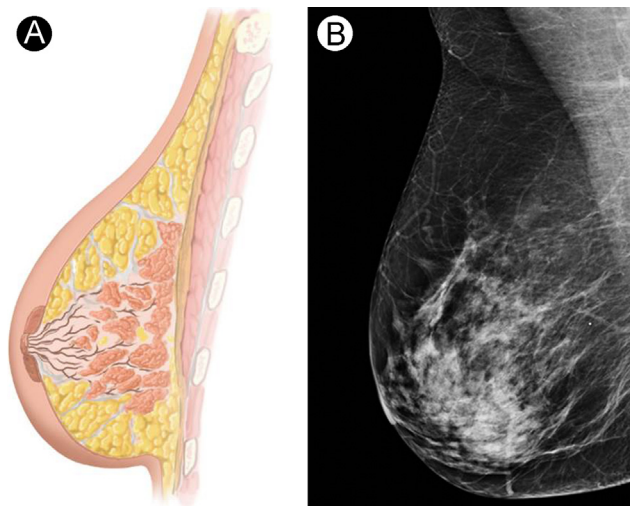


Figure 3 Normal female breast anatomy: (A) illustration of the female breast in vertical cross section and (B) medial lateral oblique (MLO) mammographic view of the normal female breast. (Color version of figure is available online.)

stimulating growth of fat and periductal connective tissue with elongation and thickening of the ductal system. Early onset of puberty in girls can result in a palpable retro-areolar tissue concerning of a “breast mass,” which should not be biopsied as tissue injury may halt breast development. With final female breast maturity, the female breast contains a balance of ducts, fibroglandular stromal tissue, and fat (Fig. 3).

Should pregnancy occur, lobular tissue in the breast reaches functional maturity. Within breast lobules, the single layer of epithelial lobular cells, with an underlying myoepithelial cell layer (Fig. 4), differentiates for lactation. Following parturition, prolactin hormone stimulates lobular epithelial cells to produce and secrete milk proteins, and oxytocin induces contraction of the myoepithelial cells surrounding the lobular alveoli to expel milk for the suckling child. After cessation of breast-feeding, the lobular epithelial cells return to their nonfunctioning state. Later in life (starting at around 40 years of age), the lobular and ductal breast tissue in the breast begins to atrophy, with involution of glandular tissue and replacement by connective tissue and fat.

Breast Anatomy and Imaging Appearances

As outlined in the previous section, the human breast is a modified cutaneous exocrine gland composed of skin and subcutaneous tissue, breast parenchyma (ducts and lobules), and supporting stroma, including fat interposed in a complex network of ligaments, nerves, arteries and veins, and lymphatics. In both men and women, the borders of the breast typically extend from the second rib superiorly to the sixth rib inferiorly with the sternum medially and the midaxillary line laterally.

The skin over the breast connects to underlying breast tissue via an anterior facial layer as well as via superficial fibrous extensions of Cooper ligaments (named in honor of Sir Astley Cooper, who advanced understanding of breast anatomy in his 1840 book on breast anatomy).² The deep parenchymal tissues of the breast are enveloped by both an anterior and posterior facial layer.³ The breast overlies the pectoralis major muscle superiorly, serratus anterior muscle laterally, and upper abdominal oblique muscles inferiorly. The female breast is usually larger than the male breast and contains a larger volume of fibroglandular tissue, whereas the male breast is almost entirely composed of fat (Fig. 2). The anatomy of the breasts, in both men and women, can be explored with multiple imaging modalities, including mammography, ultrasound, breast magnetic resonance imaging (MRI), and breast-specific gamma-ray imaging. In the remainder of the article, we discuss breast anatomy and its appearance on various imaging modalities, with a focus on the female breast.

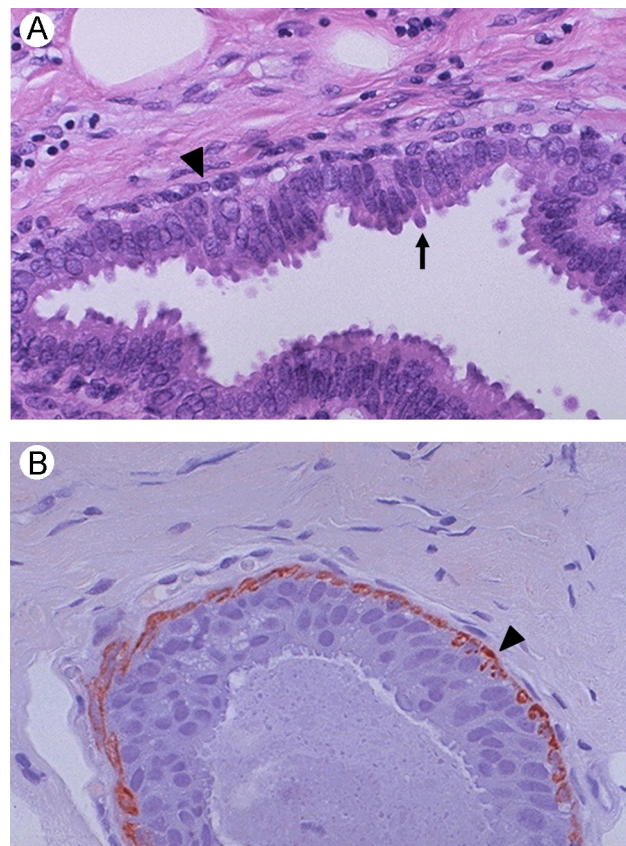


Figure 4 Normal breast histology. (A) Photomicrograph (original magnification, $\times 100$; hematoxylin and eosin (H-E) stain) of normal breast lobules. Epithelial cells line the lumen and demonstrate apocrine secretion with cytoplasmic extrusions (snouting, arrow). A layer of myoepithelial cells (arrowhead), some of which are slightly vacuolated, is seen adjacent to the epithelial cells. (B) Photomicrograph (original magnification, $\times 100$; immunoperoxidase stain with antibodies to actin) of the myoepithelial cell layer (arrowhead), which has a contractile function and is sensitive to oxytocin. (Color version of figure is available online.)

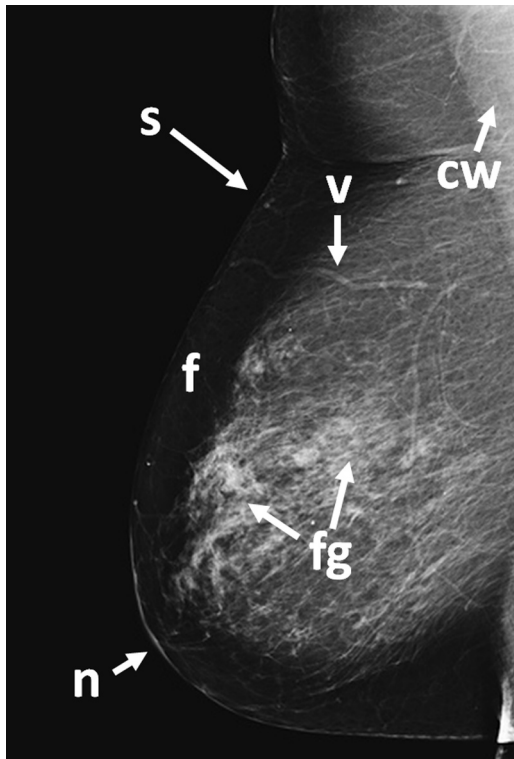


Figure 5 Normal mammographic breast anatomy. Medial lateral oblique (MLO) mammogram of the female breast overlying muscles of the chest wall (cw). The breast is covered by skin (s) with a centrally positioned nipple (n). Within the breast is fat (f), a variable amount of fibroglandular breast tissue (fg), and neurovascular structures (v).

Normal Parenchymal Breast Anatomy

Key anatomy of the breast includes skin, fat, fibroglandular breast tissue (ducts, lobules, and supporting fibrous tissue), and neurovascular structures, all positioned over the chest wall. The size and shape of the breasts on clinical examination, and the patient age, are not always predictive of the amount of internal fibroglandular tissue. Pregnancy and lactation usually double the amount of active glandular tissue relative to fat tissue in the breast. The glandular tissue regresses after cessation of lactation, sometimes resulting in a difference in breast size owing to preferential unilateral breast lactation by an infant. Between 4 and 18 main milk ducts exit at the nipple, and the ductal network is complex and heterogeneous and not always arranged symmetrically nor in a perfect radial pattern as anatomically illustrated.⁴

The most commonly used imaging tool for the breast is digital mammography. On mammography imaging, fibroglandular tissue appears white, with darker gray surrounding and interposed fat (Fig. 5). Owing to improved dynamic range over historically used screen-film mammography, skin is usually now visible on digital mammography and appears as a white edge. Striated chest wall muscle and reniform axillary lymph nodes are commonly visible on the mammographic craniocaudal and medial lateral oblique (MLO) views.

Although historical understanding of breast anatomy is based on anatomical dissections carried out by Sir Astley Cooper, with his book published in 1840, more recent work with ultrasound has updated our anatomical knowledge.⁴ On ultrasound, the gray-scale anatomy in the breast mimics its mammographic appearance (Fig. 6). Fat is hypoechoic and dark gray, whereas fibroglandular tissue is hyperechoic and white in gray-scale intensity.⁵ Muscle is usually the reference tissue and appears midgray (isoechoic). Ovoid ribs are usually visible within the chest wall and have hyperechoic white anterior margins and posterior shadowing. Note that the unenhanced computed tomography appearance of the normal breast mirrors its gray-scale ultrasound appearance (Fig. 7).

Normal Breast Vascular Anatomy

Blood supply to the breast varies based on physiological activity (eg, increased in pregnancy and lactation) and breast parenchymal volume. Premenopausal women usually have more blood volume in the breast as compared with postmenopausal women, with the largest concentration of blood vessels in the nipple.

The arterial supply to the breast is primarily derived from branches of the internal thoracic (mammary) artery, intercostal arteries, and the lateral thoracic artery. Superficially, arterial branches of the internal and lateral thoracic arteries arborize across the breast and send perforating branches deep into the breast parenchyma. Along the posterior (deep) margin of the breast, branches of the

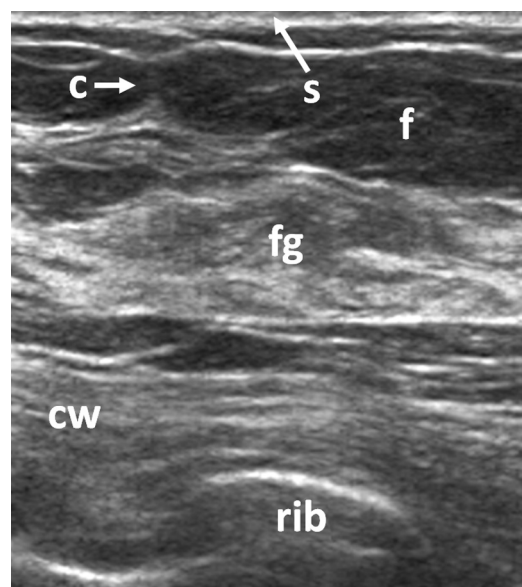


Figure 6 Normal ultrasound breast anatomy. Gray-scale sonographic imaging of the normal female breast. The breast is covered by hyperechoic skin (s). Within the breast is fat (f) and a variable amount of fibroglandular breast tissue (fg), all positioned over the chest wall (cw), with visible ribs. Note that Cooper ligaments (c) are visible as they connect to fascia and skin (s).

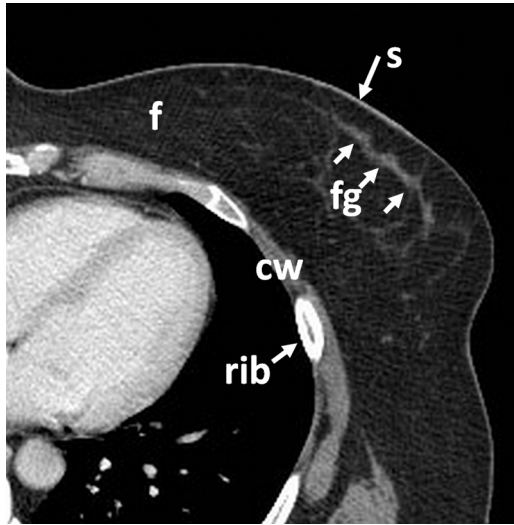


Figure 7 Normal computed tomography (CT) appearance of breast anatomy. Unenhanced CT appearance of the normal female breast. The breast is covered by hyperattenuating skin (s). Within the breast is fat (f) and a variable amount of fibroglandular breast tissue (fg), all positioned over the chest wall (cw), with visible ribs.

intercostal arteries course along the pectoralis and serratus anterior muscles and send perforating branches through chest wall musculature and out into the deep breast parenchyma. The internal thoracic artery is the dominant artery supplying the breast, and its branches supply the medial and central breast parenchyma. The lateral thoracic artery supplies the superolateral breast parenchyma. Branches of the subclavian and axillary arteries, including the thoracoacromial artery, the subscapular artery, and the thoracodorsal artery, often supply to a portion of the

superior breast parenchyma. Branches of the musculophrenic artery, a continuation of the internal thoracic artery, supply to a variable portion of the inferior breast. The anterior and posterior intercostal arteries have branches that perforate through chest wall muscles to supply the deep central breast parenchymal tissues.

The venous anatomy of the breast parallels the arterial anatomy in the deep breast tissues, with paired arterial and venous branches seen with posterior intercostal, axillary, and internal thoracic (mammary) vascular pathways. Superficially, the venous anatomy is variable and does not accompany the arterial supply. Breast veins typically lack valves, and intramammary venous anastomoses are common. Superficial veins generally drain to the center of the breast as well as the periphery and may have drainage connections to the contralateral breast. When superficial veins drain centrally, they usually converge on a periarolar circular network of veins (circulus venosus of Haller); from this venous plexus, venous blood is channeled into the internal thoracic veins medially and into the lateral thoracic veins laterally.

Blood vessels in the breast are often visible on a variety of imaging modalities, but differentiating arteries and veins is often difficult. In general, veins are larger than arteries, but this may be a consequence of breast compression (eg, mammography), chest wall compression (eg, chest pressing on breast MRI coils), or gravitational effects (eg, prone position in stereotactic biopsy and MRI) during imaging. Nonthrombosed veins are typically compressible, which often leads to fractional visualization of the vein depending on the degree of compression. On ultrasound, breast vessels are identified and differentiated based on Doppler waveform analysis (Fig. 8). Breast vessels are detectable in most female breasts, and arterial spectral Doppler analysis

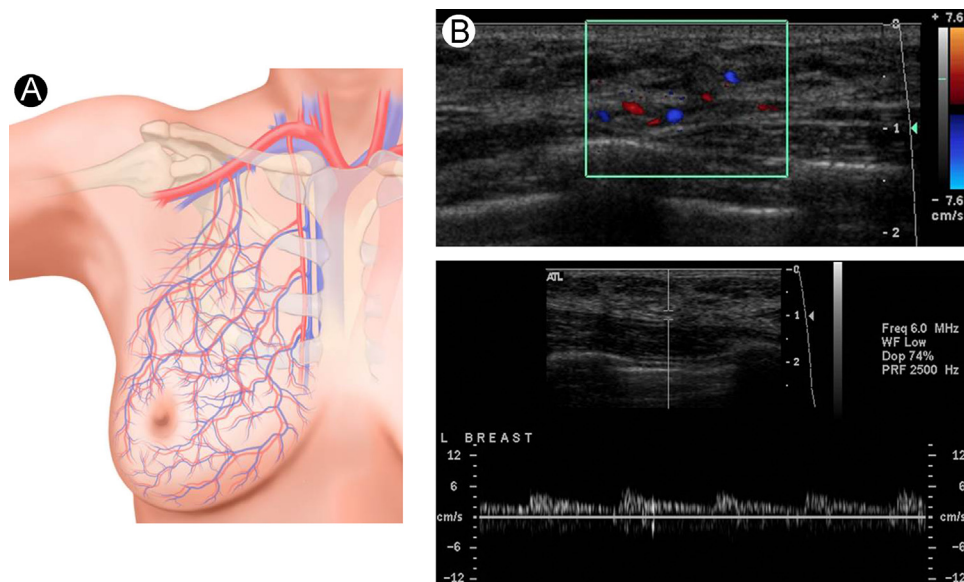


Figure 8 Normal breast parenchymal arteries and veins on ultrasound. (A) Illustration of the normal arteries and veins in the female breast. Note internal thoracic vessels and lateral thoracic vessels predominate. (B) Color Doppler sonogram shows arteries and veins within breast parenchyma adjacent to pectoralis musculature. Spectral Doppler analysis of an artery shows a low-resistance waveform with continuous diastolic flow. (Color version of figure is available online.)

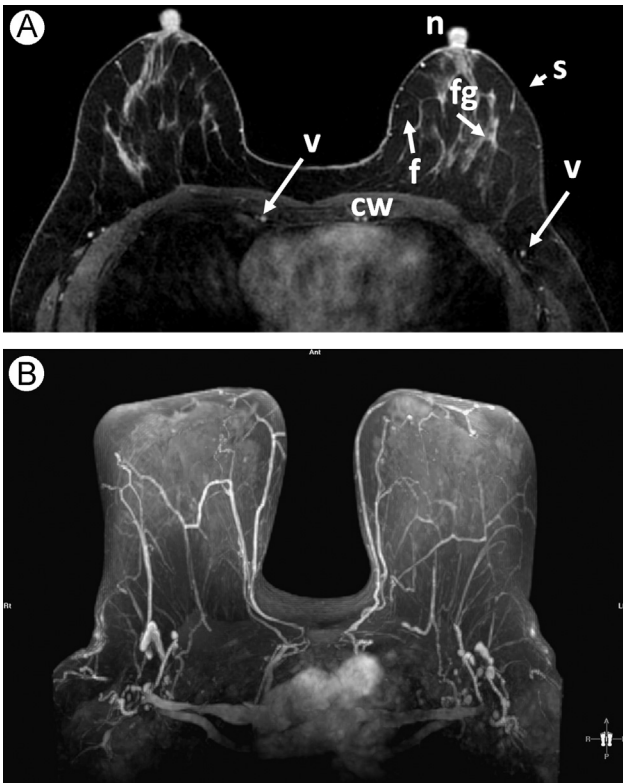


Figure 9 Normal anatomy of the breast on MRI. (A) Axial volume image for breast assessment (VIBRANT) (GE Healthcare, Waukesha, WI), obtained after administration of gadolinium contrast material (postcontrast) in a premenopausal female, shows hyperintense fibroglandular (fg) breast tissue and hypointense fat (f). Breast vessels (v) are visible, as is the enhancing nipple (n). The breast is covered by skin (s) and is positioned over the chest wall (cw). (B) Axial postcontrast maximum intensity projection (MIP) image shows collateral venous connections between the internal thoracic veins and lateral thoracic veins. Note that differentiating arterial and venous branches is difficult owing to their similar size.

usually demonstrates a low-resistance waveform. Breast vascularity may be affected by age, menstrual cycle, and vasoactive medications.⁶ Studies of resistive index calculations across age groups have shown that premenopausal women generally have lower resistive indices than postmenopausal women, but with variability in resistive index calculations within the same breast as well as overlap between the 2 age groups.⁷

On MRI, breast tissue and vascularity is often evident on both fat-sensitive (T1w) and fluid-sensitive (T2w) sequences. Breast fibroglandular tissue enhances to a variable extent, often secondary to hormonal influences on breast vascularity. On contrast-enhanced MRI of the breast, the nipple typically enhances, and breast vessels are encountered in predictable locations as previously mentioned (Fig. 9A). Veins, with collateral connections, may be demonstrated on maximum intensity projection images (Fig. 9B). Note that maximum intensity projection images are often a standard imaging data set available for review in breast MRI. Asymmetry of breast vascularity has also been found to be a potentially important marker for breast cancer. Before the rise of MRI in breast imaging, breast

vascular anatomy perhaps was not as well emphasized in training of breast imagers and interventionalists. Understanding and assessing breast vasculature allows for more accurate diagnosis of neovascularity in breast cancer, identification of vascular masses (eg, aneurysms), and identification of thrombus within breast ducts before and after biopsy and provides a roadmap for potential breast interventions.⁸ In addition, a working knowledge of breast vascular anatomy also allows the radiologist to identify vascular anomalies important to surgeons performing excisions and breast reconstructive surgery. When breast MRI is contraindicated for a patient, nuclear medicine breast-specific gamma imaging, with Technetium-99m bound to sestamibi, is available to assess breast tissue (Fig. 10). Abnormal hyperintense localization of the radiopharmaceutical is often suspicious for breast cancer.

Normal Breast Lymphatic Anatomy

The lymphatic drainage of the breast parallels the venous anatomy with intramammary and axillary lymph nodes commonly encountered on imaging studies (Fig. 11A). The rich lymphatic system of the breast originates from the

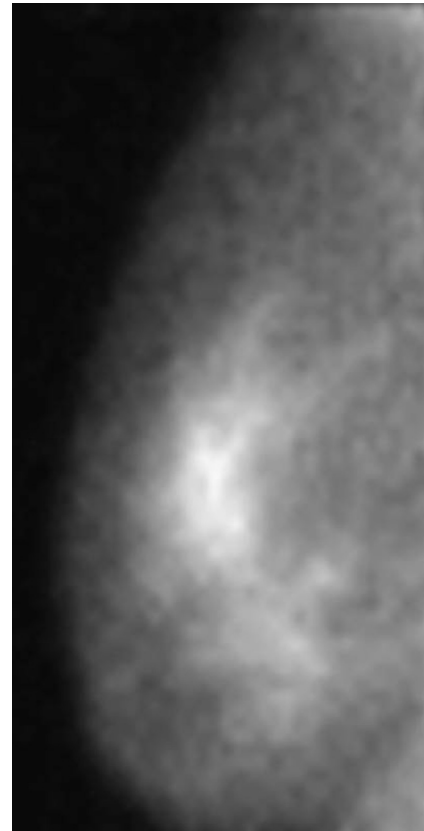


Figure 10 Nuclear medicine breast-specific gamma imaging (BSGI). Right breast MLO position imaging after intravascular administration of Technetium-99m Sestamibi, with localization of the radiopharmaceutical into fibroglandular tissue in the right breast.

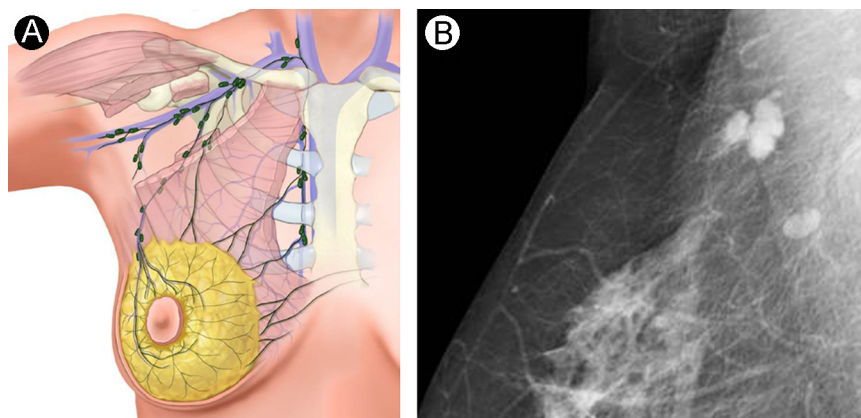


Figure 11 Normal lymphatic anatomy of the breast. (A) Illustration of the lymphatics in the female breast. Note lymphatic drainage into the lateral thoracic and subclavian chain as well as the internal thoracic chain. (B) Medial lateral oblique (MLO) mammogram of the female breast demonstrating reniform-shaped axillary lymph nodes, of variable size, in the left axilla. (Color version of figure is available online.)

walls of mammary ducts and from interlobular connective tissue. Deep lymphatic channels communicate with the more superficial cutaneous lymphatic plexus, especially around the nipple in the subareolar plexus. Lymphatic drainage from the subareolar plexus is primarily to axillary lymph nodes. Reniform-shaped axillary lymph nodes, of variable size, are commonly visible on the mammographic MLO view (Fig. 11B). Normal lymph nodes are hypervascular and typically have a thin (<3 mm), mildly lobulated cortex and fat-filled hilum. Outside of mammography, ultrasound, and breast MRI, the lymphatic drainage in the breast is most commonly assessed with nuclear medicine lymphoscintigraphy. Using lymphoscintigraphy, the sentinel lymph node can be identified for surgical resection and if it is found to be histopathologically free of cancer, the patient can be spared a full axillary lymph node dissection (Fig. 12).

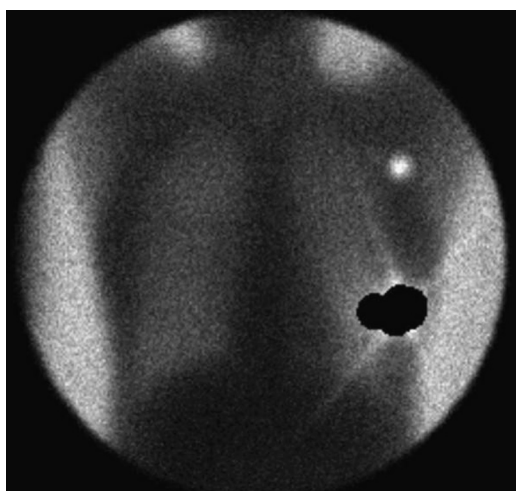


Figure 12 Nuclear medicine lymphoscintigraphy. Frontal gamma camera image of the chest after periareolar intradermal injections of Technetium-99m sulfur colloid in the left breast, with lymphatic transit of the radiopharmaceutical into a sentinel lymph node in the left axilla.

Summary

Knowledge of normal breast anatomy on the modern variety of imaging modalities used in breast imaging is important for an interventionalist. Breast fibroglandular tissue volumes can vary with age, with many women having a predominance of fat within the breasts after menopause. Assessing breast vascularity has become a key goal in breast cancer detection, and knowledge of breast lymphatic drainage is important to assist the breast surgeon and oncologist in correctly staging the extent of disease.

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