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Advances in Breast Ultrasound Imaging: A Comprehensive Review For Radiologists, Nursing, and Health Assistant

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Abstract
Background: Breast ultrasound has evolved from a supplementary tool into a fundamental modality in breast imaging. While mammography remains the primary screening method, its sensitivity is reduced in women with dense breast tissue. Ultrasound provides a real-time, high-resolution assessment that is not limited by tissue density, making it invaluable for detecting and characterizing both palpable and non-palpable abnormalities.
Aim: This comprehensive review aims to detail the current role, techniques, and clinical significance of breast ultrasound. It covers its advantages, technological advancements, standardized reporting via the BI-RADS lexicon, and its integral place in diagnostic and interventional breast care.
Methods: The review synthesizes established practices and guidelines, describing the systematic technique for performing breast ultrasound, the use of high-frequency linear transducers, and the critical interpretation of sonographic features such as lesion shape, margin, orientation, and posterior acoustic characteristics.
Results: When used adjunctively with mammography, breast ultrasound significantly increases sensitivity for breast cancer detection, particularly in dense breasts. However, this comes with an increased rate of false-positive. Standardized BI-RADS reporting minimizes variability and guides management, from follow-up for probably benign lesions (BI-RADS 3) to biopsy for suspicious masses (BI-RADS 4/5). The modality is also essential for guiding interventions and monitoring treatment response.
Conclusion: Breast ultrasound is an indispensable, safe, and versatile component of modern breast imaging. Its effectiveness relies on skilled personnel, advanced technology, and adherence to standardized protocols to improve diagnostic accuracy, guide patient management, and enhance interdisciplinary healthcare outcomes.
Keywords: Breast Ultrasound, BI-RADS, Breast Cancer, Dense Breast Tissue, Sonography, Mammography, Image-Guided Biopsy, Interprofessional Care

Introduction
Breast ultrasound has evolved into a fundamental imaging modality in the evaluation of breast disease, complementing and extending the capabilities of conventional mammography.[1] While mammography remains the gold standard for population-based breast cancer screening, especially in organized screening programs, its performance is significantly affected by breast density. In women with dense breast parenchyma, the sensitivity of mammography may be reduced due to the masking effect of fibroglandular tissue, which can obscure small or subtle lesions and thereby delay diagnosis.[1] In this context, breast ultrasound has become particularly valuable as it provides real-time, high-resolution assessment that is not impeded by tissue density, enabling improved detection and characterization of both palpable and non-palpable abnormalities. Consequently, ultrasound and magnetic resonance imaging (MRI) have progressively expanded their role as supplementary tools in breast cancer screening, especially for high-risk groups and for women with dense breasts.[1] Ultrasound offers several practical advantages: it is widely available, relatively low-cost, free of ionizing radiation, and well-tolerated by patients. When used in conjunction with mammography, it enhances lesion detection, particularly for small invasive

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cancers that may be mammographically occult. The combined use of mammography and ultrasound has been reported to increase the sensitivity for breast cancer detection to 97.3%, underscoring the clinical importance of a multimodality approach.[2] However, this improvement in sensitivity is accompanied by an increased burden of benign findings and a measurable false positive rate, with the false positive rate of ultrasound estimated at 2.4%.[2] These performance characteristics highlight the need for careful image interpretation and standardized reporting to balance early cancer detection against unnecessary biopsies and patient anxiety.

To address variability in technique, description, and reporting, guidelines for breast sonography terminology and assessment have been codified in the 2013 American College of Radiology Breast Imaging Reporting and Data System (ACR BI-RADS) Atlas.[1] This lexicon provides a structured vocabulary for describing lesion features, including shape, margin, orientation, echo pattern, posterior acoustic features, and associated findings, promoting consistency among radiologists and facilitating clear communication with referring clinicians. Multiple descriptive elements are integrated into a final assessment category that reflects the level of suspicion for malignancy, with the overall assessment commonly driven by the most concerning imaging characteristic.[2] The adoption of BI-RADS-based ultrasound reporting has been instrumental in standardizing clinical practice, enabling outcome auditing, and supporting research into risk stratification and management pathways. Within this framework, breast ultrasound now represents an indispensable component of contemporary breast imaging, contributing to early detection, accurate diagnosis, and appropriate patient management in both screening and diagnostic settings.[1],[2]

Anatomy and Physiology

Breast ultrasound plays a central role in contemporary breast imaging, particularly in the localization of both palpable and nonpalpable masses prior to surgical excision, where precise preoperative mapping is essential for guiding surgeons and optimizing clinical outcomes.[3] A thorough understanding of breast anatomy and physiology enhances the radiologist’s ability to interpret sonographic findings accurately and to differentiate between normal structures, benign variants, and pathological processes. The breast is composed of a complex arrangement of glandular, stromal, and fatty tissues, structurally organized to support both hormonal responsiveness and lactational function. At the core of this architecture are 15 to 20 lobules, each containing smaller branching ducts that converge within the terminal duct lobular units (TDLUs), which represent the functional and histological units where the majority of breast pathologies, including carcinoma and benign proliferative disorders, originate. These ducts drain toward the nipple through a single lactiferous sinus, forming the physiological pathway for milk transport during lactation. Anatomically, the breast can be divided into three principal zones: the premammary, mammary, and retromammary compartments. The premammary zone lies immediately deep to the skin and is predominantly composed of subcutaneous fat, which provides contour and serves as an acoustic window on ultrasound. The mammary zone contains the dense fibroglandular tissue responsible for milk production and ductal transport, while the retromammary zone comprises deeper fat, lying superficial to the pectoralis muscle. These tissues are contained between the superficial fascia beneath the dermis and the deep fascial layer overlying the pectoral musculature. Ultrasound imaging captures these layers as alternating hyperechoic and hypoechoic bands, creating a predictable sonographic pattern that helps radiologists distinguish anatomical noise from pathologic findings.[4] The skin appears as a hyperechoic superficial line with fine fibrous bands, followed by hypoechoic subcutaneous fat lobules. Beneath this lies the mammary parenchyma, typically hyperechoic because of its fibroglandular composition. Posterior to the parenchyma, the retromammary fat again appears hypoechoic, and finally, the pectoralis major muscle is visualized as a relatively hyperechoic structure due to its fibrous content.

The anatomy of the axilla is of equal clinical importance, particularly when assessing nodal disease or planning image-guided biopsies. The axillary region contains multiple lymph nodes in addition to the axillary artery and vein, forming a major conduit for lymphatic drainage from the breast. Normal axillary lymph nodes exhibit a characteristic ultrasound appearance: an echogenic fatty hilum surrounded by a thin hypoechoic cortex typically measuring less than 3 mm. Deviations from this morphology, such as cortical thickening, loss of the fatty hilum, or altered vascularity, may raise suspicion for malignancy and prompt further diagnostic evaluation.[4] The vascular supply to the breast arises mainly from branches of the axillary and subclavian arteries, including the internal mammary (or internal thoracic), lateral thoracic, and thoracoacromial arteries. This robust vascular network supports glandular function and facilitates inflammatory or neoplastic dissemination. Lymphatic drainage predominantly flows toward the ipsilateral axillary nodal basin, which accounts for approximately 90% of lymphatic outflow, while the internal mammary chain contributes the remaining 10%.[5] Although rare, contralateral drainage may occur following surgical disruption, such as after mastectomy, representing an important consideration in postoperative imaging and oncology surveillance.[5] Through comprehensive appreciation of these anatomical and physiological principles, clinicians are better equipped to leverage ultrasound's diagnostic capabilities and interpret findings in the context of normal breast architecture and pathological evolution [5].

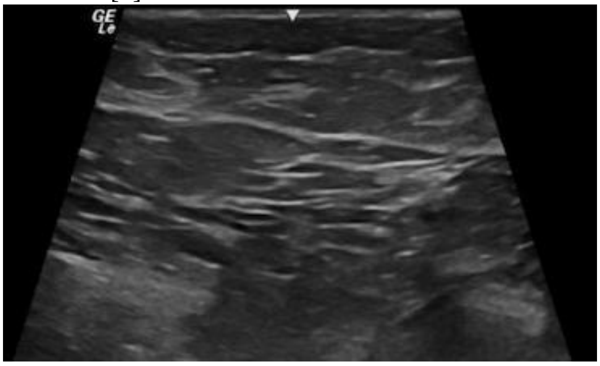

Fig. 1: Sonographic cross-sectional view of benign breast tissue with typical hyperechoic.

Indications

Breast ultrasound is a versatile and widely utilized imaging modality with numerous clinical indications, particularly in situations where mammography may be limited or when additional diagnostic clarification is required.[6] One of the most common reasons for performing breast ultrasound is the evaluation of a palpable lump identified during a clinical breast examination. Ultrasound provides real-time visualization that helps distinguish cystic from solid lesions and guides subsequent management. It is equally valuable in assessing axillary lymphadenopathy detected on mammographic imaging, allowing for detailed characterization of nodal morphology, evaluation of cortical thickness, and determination of whether image-guided biopsy is warranted. Ultrasound is the first-line imaging choice in women younger than 40 years who present with breast symptoms, as dense breast tissue in this age group can obscure mammographic findings. It is also a safe and preferred modality in pregnant or lactating women because it avoids ionizing radiation while providing excellent soft-tissue contrast. When mammography reveals a suspicious abnormality, such as an architectural distortion or focal asymmetry, targeted ultrasound frequently serves as the next diagnostic step to refine the assessment and facilitate biopsy planning.[6] Additional symptoms such as nipple discharge, skin retraction, or nipple inversion also warrant further evaluation with ultrasound, as these features may be associated with underlying ductal or subareolar pathology. Breast ultrasound is particularly useful in patients with postoperative or surgical scarring that may mimic malignancy on mammography. In men, ultrasound aids in the evaluation of gynecomastia, offering a clear distinction from malignant processes. Implant evaluation is another important indication, as ultrasound helps identify intracapsular and extracapsular ruptures and contributes to comprehensive implant surveillance. Beyond diagnostic applications, ultrasound is integral to procedural guidance, including needle-guided percutaneous breast biopsies, cyst aspirations, and preoperative localization. It also plays a key role in monitoring therapeutic response, particularly in patients undergoing neoadjuvant chemotherapy, where changes in tumor size and characteristics can be tracked noninvasively over time.[6] Through this broad range of applications, breast ultrasound remains a critical tool in modern breast imaging and patient care.

Contraindications

While breast ultrasound is a highly valuable adjunctive imaging technique, it is not without limitations, and certain contraindications must be considered to ensure optimal patient care. The most significant limitation is that breast ultrasound should not be used as a sole screening tool for breast cancer.[7] Although ultrasound can detect lesions that may be mammographically occult, particularly in dense breast tissue, its use alone lacks the sensitivity and specificity required for population-based screening. Mammography remains the established primary screening modality because of its proven ability to detect microcalcifications and early-stage malignancies, features that ultrasound may not reliably demonstrate. Relying exclusively on ultrasound for screening increases the risk of missing subtle pathologies, potentially delaying diagnosis. Instead, breast ultrasound is best employed as a complementary technique, providing targeted evaluation and further characterization of abnormalities identified on mammography or clinical examination.

Fig. 2: Ultrasound image of a right breast mass.

Equipment

Advancements in high-frequency ultrasound technology over the past decade have significantly enhanced breast imaging, enabling radiologists to obtain clearer, more detailed views of superficial structures and subtle lesions. Modern breast ultrasound employs high-frequency linear transducers, typically ranging from 7.5 MHz to 23 MHz, with many systems now incorporating high-density or single-crystal probe elements. These innovations contribute to improved lateral spatial resolution, which is particularly important for distinguishing fine morphological features such as lesion margins, subtle architectural distortions, and small internal echoes within cystic or complex masses.[8] The American College of Radiology (ACR) recommends the use of a linear-array transducer with a center frequency of at least 10 MHz, though contemporary practice often favors probes operating at 12 MHz or higher to achieve optimal resolution. Higher frequencies, while excellent for detail, have limited penetration, making lower-frequency settings preferable for imaging deep tissue structures or evaluating patients with large breasts. Most modern ultrasound devices include tissue harmonic imaging (THI) as a standard feature. THI enhances image clarity by reducing noise, reverberation, and near-field artifacts, thereby improving the visualization of both superficial and deeper tissues. Another widely available technology is real-time compound imaging, in which multiple frames acquired at different insonation angles are combined to improve contrast resolution and edge definition. This method is particularly valuable in the assessment of lesion margins, helping to distinguish benign from malignant features. Panoramic imaging, which extends the field of view to capture wide or elongated anatomical regions, is also useful for documenting large masses or mapping multifocal disease. Additional innovations such as image splicing and volumetric imaging allow the generation of 3D reconstructions, offering more comprehensive perspectives on complex lesions.

Recent developments in ultrasound equipment include wireless linear-frequency probes paired with mobile imaging application software, providing portable, point-of-care imaging capabilities without sacrificing essential resolution.[8] This technological shift is particularly promising for screening in remote locations, bedside examinations, and intraoperative imaging where traditional console-based systems may be impractical. Beyond hardware advances, software-driven tools have further refined diagnostic precision. Many ultrasound platforms now include computer-aided detection (CAD) systems capable of automatically segmenting masses, highlighting suspicious regions, and offering real-time analytical support. While CAD does not replace expert interpretation, it enhances workflow efficiency and may improve sensitivity in detecting subtle abnormalities. Producing high-quality diagnostic images also requires meticulous technical optimization. Radiologists and sonographers must adjust parameters such as focal zone placement, depth, time gain compensation (TGC), and overall gain to ensure accurate lesion characterization.[9] The focal zone should be positioned at or just posterior to the area of interest—typically within the anterior or middle third of the breast depth—to ensure maximal resolution. Proper gray-scale calibration is essential; normal subcutaneous fat should appear medium gray rather than anechoic, as excessively low gain may obscure tissue planes while excessively high gain may make simple cysts appear falsely solid. Compound imaging, created by averaging multiple frames, can enhance margin visualization and reduce speckle noise, improving diagnostic confidence. Through the integration of advanced hardware, sophisticated software, and careful technical execution, contemporary ultrasound systems offer unparalleled versatility and diagnostic accuracy in breast imaging.

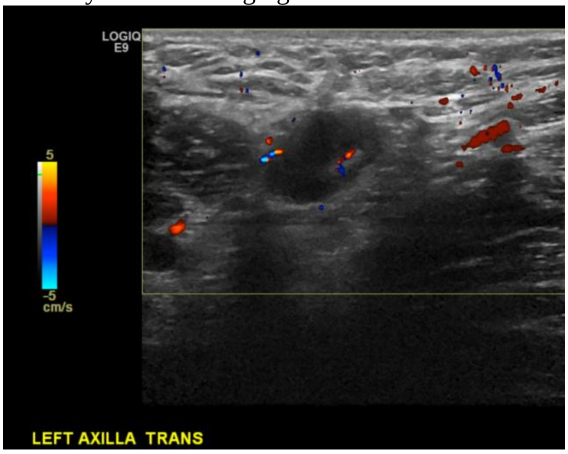

Fig. 3: Biopsy proven malignant left axillary lymph node with cortical thickening of 5 mm.

Personnel

Breast ultrasound requires skilled personnel who possess both technical proficiency and clinical understanding of breast anatomy, pathology, and imaging principles. In most clinical settings, the examination may be performed by a trained ultrasound technician (sonographer), a radiologist, or a referring clinician who has undergone appropriate education and competency-based training. Sonographers play a vital role as they are typically responsible for obtaining high-quality images, adjusting technical parameters, and ensuring that all relevant anatomical regions and suspected abnormalities are thoroughly evaluated. Their expertise directly influences diagnostic accuracy, particularly in the detection of subtle lesions or atypical presentations. Radiologists, especially those specializing in breast imaging, interpret the sonographic findings and integrate them with clinical history and other imaging modalities such as mammography or MRI. They may also personally perform targeted ultrasound examinations when a higher level of expertise is required, particularly for complex cases or interventional procedures. Referring clinicians—including breast surgeons, obstetrician-gynecologists, and primary care physicians—may also perform focused ultrasound exams if they have completed appropriate training and demonstrated competency. Regardless of the provider, adherence to standardized scanning protocols and ongoing professional development is essential for maintaining high diagnostic standards, ensuring patient safety, and optimizing the clinical utility of breast ultrasound in both screening adjuncts and diagnostic workflows.

Preparation

Breast ultrasound is a straightforward, noninvasive imaging procedure that generally requires minimal patient preparation, making it highly accessible and convenient in a variety of clinical settings. Because the examination focuses on the breast and axillary regions, patients are advised to remove any jewelry, such as necklaces or piercings, that may interfere with the transducer's access to the area of interest.[10] Wearing loose, comfortable clothing is recommended, as patients will typically be asked to undress from the waist up and change into a medical gown to allow full exposure of the breasts and upper chest. This ensures unobstructed access for the sonographer and facilitates optimal positioning during the scan. Although no dietary restrictions or pre-procedural medications are necessary, patients may be asked to provide relevant clinical information, including a history of prior breast surgeries, breast symptoms, or previous imaging studies. Such details help guide a focused and accurate examination. Patients should also be informed that the procedure is painless, though mild pressure from the transducer may be experienced, especially when scanning tender or symptomatic areas. For lactating women, it can be helpful to nurse or pump before the examination to reduce ductal distension, which may otherwise obscure visualization. Overall, the simplicity of preparation contributes to the efficiency and widespread utility of breast ultrasound in both routine diagnostic evaluation and targeted assessment of breast concerns [10].

Technique or Treatment

The technique of breast ultrasound is grounded in a systematic, reproducible approach that begins before the transducer is even applied to the skin. Initial imaging should be preceded by a thorough clinical assessment, including a full clinical breast examination and, when appropriate, correlation with the patient's own breast self-examination (BSE) findings. This clinical step allows the examiner to localize and validate all palpable abnormalities reported by either the patient or the physician and to target ultrasound evaluation accordingly.[11] Once the clinical examination is complete, a bilateral breast ultrasound is typically performed in a sequential fashion, with the transducer sweeping across the entire breast surface to ensure comprehensive coverage. Standard sonographic assessment divides each breast into four principal quadrants—upper outer, upper inner, lower outer, and lower inner—along with the retroareolar region and axillary tail. This regional framework helps in documenting lesion location in a manner that is consistent and easily communicated. Any lesion identified during the examination should be recorded using the "breast o'clock" system, assigning a clock-face position and distance from the nipple to facilitate accurate follow-up, comparison with other imaging modalities, and precise surgical or biopsy planning.[11] This method of localization is especially important in cases with multiple lesions or in longitudinal follow-up where subtle changes in size or morphology must be tracked.

Fig. 4: Simple cyst of the left breast.

The most widely used scanning technique involves a radial or star-shaped pattern of sweeps, often supplemented by orthogonal, superior-to-inferior and medial-to-lateral passes. The transducer is moved in overlapping strokes to avoid skipping small lesions, with careful extension of the field of view to include the axillary tail, parasternal margin, and infraclavicular and supraclavicular regions when clinically indicated. Gentle transducer pressure is applied to optimize acoustic coupling and reduce motion artifacts, while avoiding excessive compression that could obscure or distort superficial lesions or alter the appearance of compressible structures such as cysts. The retroareolar region requires particular attention due to its dense parenchyma and the presence of converging ducts, which are often sites of clinically significant pathology. Dense tissue and the nipple itself frequently cast posterior acoustic shadowing that limits visualization of deeper structures. To overcome this limitation, several techniques can be employed. Angling the probe cranially or caudally relative to the nipple can reposition the acoustic window and reduce shadowing from the nipple-areolar complex. Alternatively, a gel standoff pad can be placed over the nipple to modify the near-field characteristics and allow the focal zone to be positioned more superficially. Adjustment of time gain compensation (TGC) and overall gain may further improve conspicuity of ducts and parenchymal detail posterior to the nipple, enhancing evaluation of retroareolar masses, duct ectasia, or intraductal lesions.[11] Accurate and standardized measurement of lesions is a critical component of breast ultrasound reporting. The longest axis of the lesion should be measured first, with the dimensions recorded to the nearest millimeter or centimeter, depending on the protocol. In total, three orthogonal measurements are recommended. The first corresponds to the maximum lesion length, the second to a perpendicular dimension within the same imaging plane, and the third to a measurement obtained on an orthogonal plane relative to the initial view. This tri-planar approach ensures that the full spatial extent of the lesion is characterized, facilitates comparison across subsequent examinations, and provides essential information for surgical or interventional planning.[11]

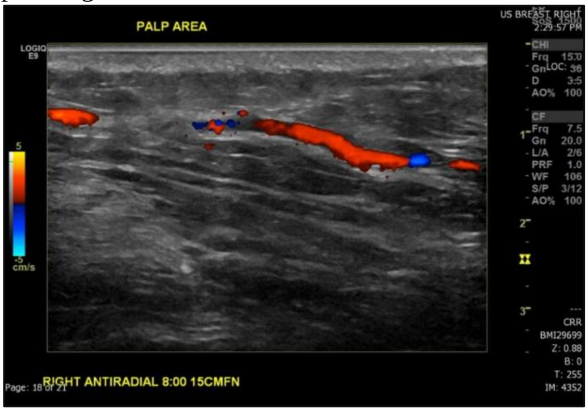

Fig. 5: Ultrasound image of the patient's area of palpable concern in the right breast.

Interpreting breast ultrasound also requires an understanding of normal background echotexture, which varies depending on the relative proportions of fat and fibroglandular tissue. Three general categories are described. In a homogeneous fatty background, fat constitutes the majority of breast tissue, producing a relatively uniform hypoechoic pattern with scattered echogenic fibrous strands. In a homogeneous fibroglandular pattern, echogenic fibroglandular parenchyma predominates beneath the subcutaneous fat, leading to a brighter, more uniform echotexture. A heterogeneous background echotexture consists of mixed echogenicity, with interspersed islands of fibroglandular tissue and fat, which can sometimes obscure small lesions or complicate differentiation between normal and abnormal structures. Recognizing these patterns helps the examiner distinguish pathology from physiologic variation and anticipate areas where lesion detection may be more challenging.[11] When a mass is identified, its sonographic features must be documented using standardized descriptors, typically drawn from the BI-RADS ultrasound lexicon. The shape of the lesion is first assessed and characterized as oval, round, or irregular. Oval masses often suggest benignity, particularly when associated with smooth margins, whereas irregular shapes raise concern for malignancy. The orientation of the lesion is then evaluated as parallel (wider-than-tall) or not parallel (taller-than-wide). Lesions oriented parallel to the skin surface are more often benign, while a nonparallel, vertically oriented mass may indicate invasive growth crossing tissue planes. Margin characteristics are equally important. A mass may have circumscribed margins, which are smooth and well defined, commonly seen in benign entities such as simple cysts and fibroadenomas. Noncircumscribed margins are further described as indistinct, angular, microlobulated, or spiculated. Indistinct margins may reflect infiltrative growth or desmoplastic reaction, angular and microlobulated borders suggest irregular proliferation, and spiculated margins are highly suspicious for malignancy. The internal echo pattern is documented as anechoic, hyperechoic, hypoechoic, isoechoic, complex cystic and solid, or heterogeneous. Anechoic lesions with thin walls and posterior enhancement typically correspond to simple cysts, while hypoechoic solid masses or complex cystic and solid lesions warrant closer scrutiny and often biopsy.

Posterior acoustic features provide additional diagnostic clues. Some lesions exhibit no significant posterior changes, while others demonstrate acoustic enhancement, shadowing, or a combined pattern of both. Enhancement, manifested as increased echogenicity deep to the lesion, is common in cystic structures or some solid benign tumors, whereas shadowing suggests increased attenuation, often associated with fibrotic or malignant processes. A mixed pattern may occur in complex or partially calcified lesions. These posterior characteristics, when integrated with shape, margin, and internal echotexture, strengthen the overall assessment and guide management decisions.[11] Calcifications, though more optimally evaluated with mammography, may also be detected on ultrasound. When present, their location should be carefully documented, noting whether they are confined within a mass, located outside a mass in the surrounding parenchyma, or arranged along ducts in an intraductal pattern. Associated sonographic features must also be systematically reviewed. These include architectural distortion, skin thickening, or skin retraction, all of which can suggest underlying malignancy or post-surgical change. The presence and pattern of vascularity, assessed with color or power Doppler, may be described as absent, rim-dominant, or internal, recognizing that increased internal vascularity can be a feature of malignancy but is not specific. Changes in ductal morphology, such as dilation, irregularity, or the presence of intraductal masses, should be documented, particularly in patients presenting with nipple discharge or retroareolar symptoms. In settings where elastography is available, qualitative or quantitative assessment of tissue stiffness can add further information, with lesions broadly categorized as soft, intermediate, or hard relative to surrounding parenchyma. Increased stiffness may be associated with malignancy, although overlap with benign fibrotic lesions exists. Elastographic findings are therefore interpreted in conjunction with the grayscale and Doppler features rather than in isolation.

Several sonographic findings have a pathognomonic or highly characteristic appearance, allowing confident diagnosis without additional invasive testing in the appropriate clinical context. Simple cysts appear as round or oval anechoic lesions with thin walls, posterior acoustic enhancement, and no internal vascularity. Clustered microcysts present as small, grouped anechoic foci that may represent benign fibrocystic change. Complicated cysts, containing low-level internal echoes or fluid–debris levels, can still be benign but may require short-interval follow-up or aspiration. Lesions that clearly reside in or on the skin, such as epidermal inclusion cysts, have a distinct superficial location, sometimes with a visible tract to the skin surface. Foreign bodies, postoperative seromas, and fat necrosis demonstrate characteristic appearances—such as echogenic foci with posterior shadowing or oil cysts—that, when correlated with history, can be confidently diagnosed on ultrasound. Normal and reactive lymph nodes show an oval shape with a preserved echogenic hilum and thin cortex, whereas pathologic nodes may lose the hilum and develop cortical thickening. Vascular abnormalities, including Mondor disease and arteriovenous malformations, exhibit specific vascular patterns on Doppler imaging. By integrating meticulous technique with standardized descriptive criteria and clinical correlation, breast ultrasound serves as a powerful tool for diagnosis, treatment planning, and follow-up in patients with a wide spectrum of breast conditions.[11]

Complications

Breast ultrasound is widely regarded as one of the safest imaging modalities available in clinical practice, primarily because it is noninvasive and does not expose patients to ionizing radiation. As a result, the procedure itself carries virtually no inherent complications. The acoustic energy used in diagnostic ultrasound operates at levels far below those known to cause tissue damage, making it suitable for use across all patient populations, including pregnant or lactating women, adolescents, and individuals requiring repeated examinations. Its safety profile is one of the major advantages of ultrasound as an adjunct in breast imaging, contributing to its widespread use in both screening adjuncts and diagnostic evaluation. Although the modality itself is free of direct complications, certain indirect issues may arise in rare cases. Mild discomfort can occur when pressure is applied to tender or inflamed areas, but this is temporary and not considered a true complication. Additionally, user-dependent variability in technique or interpretation may lead to diagnostic limitations rather than procedural risks. For example, inadequate imaging of deep or obscured tissue, or mischaracterization of subtle lesions, can occasionally delay diagnosis or prompt unnecessary follow-up. When ultrasound is used to guide interventional procedures, such as biopsies or aspirations, risks are associated with the intervention rather than with the imaging itself, including bleeding, infection, or bruising. Nonetheless, these are related to the procedure performed under ultrasound guidance, not to ultrasound technology. Overall, diagnostic breast ultrasound remains exceptionally safe, with no clinically significant adverse effects attributable to the imaging process itself.

Clinical Significance

The clinical significance of breast ultrasound lies in its pivotal role as both a diagnostic and follow-up imaging modality, particularly in the context of lesions categorized as BI-RADS 2 and 3. Ultrasound is uniquely positioned to refine lesion characterization over time, offering dynamic assessment of morphology and internal architecture that complements mammography and clinical evaluation.[12] When used as part of routine follow-up for probably benign findings, ultrasound allows radiologists to monitor for subtle changes in size, shape, margin, and echotexture, thereby facilitating early identification of evolving malignancies while safely avoiding unnecessary biopsies in stable or clearly benign lesions. This longitudinal perspective is especially valuable in BI-RADS 3 lesions, where the balance between early detection and over-intervention is delicate. Stable imaging over the recommended follow-up period may support downgrading to BI-RADS 2, whereas interval growth or the development of suspicious features prompts timely escalation to biopsy or further diagnostic workup.[12] Incorporating ultrasound as a standard follow-up tool also promotes more accurate recharacterization of lesions even during the initial assessment. Features that may appear equivocal or indeterminate on a single exam may be better understood in light of subsequent imaging, revealing biologic behavior such as progression, regression, or cyclic change. This is particularly relevant for lesions influenced by hormonal status, such as fibroadenomas or cyst complexes, in which timing across the menstrual cycle and longer-term follow-up can clarify their benign nature.[13] Ultrasound's capacity for real-time, targeted examination also means that any new symptoms or palpable abnormalities can be correlated immediately with prior findings, reinforcing or revising the original interpretation.

A complete ultrasound examination has limited value unless it is supported by a clear, structured, and comprehensive report. Standardized reporting is central to the clinical impact of breast ultrasound, as it ensures that key details are documented and communicated effectively to referring clinicians and surgeons.[12] Every report should begin with the indication for the study, which provides clinical context and guides the focus of the examination. This is followed by a description of the technique, including whether the examination was unilateral or bilateral, the extent of tissue interrogated (for example, including the axillary tail and regional lymph nodes), and any special maneuvers or adjunctive imaging such as Doppler or 3D reconstructions. When applicable, comparison with previous studies should be explicitly stated, as stability or interval change is central to BI-RADS categorization and follow-up recommendations. Lesions identified during the examination must be documented with meticulous attention to location and measurement. Standard practice involves measuring masses in both transverse and longitudinal planes and providing three orthogonal dimensions. These measurements should be recorded to the nearest millimeter or centimeter and used consistently in follow-up studies to assess interval change. The location is described using the clock-face method, along with the distance from the nipple and depth relative to the skin and chest wall, ensuring precise localization for future imaging or intervention.[12] The echogenicity of each mass must also be recorded, typically as hypoechoic, hyperechoic, isoechoic, or heterogeneous, since echo pattern is one of the primary descriptors used in risk stratification.

The lexicon of the ultrasound BI-RADS system (US BI-RADS) provides six major categories of morphological descriptors that underpin standardized lesion assessment.[12] These include mass shape (oval, round, or irregular), orientation (parallel or not parallel), margin (circumscribed or noncircumscribed, with further specification as indistinct, angular, microlobulated, or spiculated), echo pattern (anechoic, hypoechoic, isoechoic, hyperechoic, complex cystic and solid, or heterogeneous), posterior acoustic features (none, enhancement, shadowing, or combined), and associated features such as calcifications, architectural distortion, or skin changes. Adherence to this lexicon reduces interobserver variability and provides a common language for radiologists, facilitating multi-disciplinary communication and evidence-based management decisions.[12] Clinically, certain morphologic features are strongly associated with benignity and allow for confident classification as BI-RADS 2 or 3. Benign-appearing lesions often demonstrate smooth and well-circumscribed margins, reflecting noninfiltrative growth patterns.[13] Their echogenicity is typically hyperechoic, isoechoic, or only mildly hypoechoic relative to surrounding fibroglandular tissue, as seen in many fibroadenomas and lipomas. A thin echogenic capsule or well-defined border further supports a benign diagnosis, providing a clear interface between the lesion and adjacent parenchyma. Shape and orientation are also key clues: benign masses frequently appear ellipsoid and are wider than tall, oriented parallel to the skin surface, which suggests growth along normal tissue planes rather than vertical infiltration.[13] Additional benign features include gently macrolobulated contours with fewer than three lobulations and posterior acoustic enhancement, commonly observed in cysts and some solid benign tumors. These features, when present in combination and in an appropriate clinical context, justify a conservative management approach, often with routine follow-up rather than immediate biopsy.

Conversely, a distinct set of morphologic criteria is more commonly associated with malignancy and underpins higher BI-RADS categories warranting tissue diagnosis.[14] Malignant lesions classically present as hypoechoic masses; however, they may occasionally appear hyperechoic, particularly in the presence of desmoplastic reaction or infiltrative processes that alter surrounding stroma.[14] Spiculated margins are among the most ominous features, suggesting infiltration into adjacent tissues, while ill-defined or indistinct borders and associated architectural distortion also raise strong suspicion for invasive disease. These features can reflect tumor-induced fibrosis or disruption of normal parenchymal architecture. Posterior acoustic shadowing is another hallmark often seen in invasive carcinomas, corresponding to increased attenuation through dense, fibrotic tumor tissue.[14] A taller-than-wide orientation indicates that the lesion is growing across tissue planes, violating the natural architecture of the breast, and is therefore considered a highly suspicious feature. When microcalcifications are visible on ultrasound—typically appearing as echogenic foci with or without shadowing—their presence in a suspicious mass further strengthens the likelihood of malignancy, especially when correlated with mammographic findings.[14] The clinical significance of recognizing these feature patterns extends far beyond descriptive imaging. By accurately applying US BI-RADS descriptors and assigning appropriate BI-RADS assessment categories, radiologists directly influence patient management pathways, from reassurance and routine surveillance to urgent biopsy and referral to oncologic services. For example, a lesion with classic benign features in a young woman may be safely followed with short-interval imaging, minimizing invasive procedures and attendant anxiety. In contrast, a small but morphologically aggressive lesion detected in a screening context can prompt early biopsy and potentially life-saving intervention. The specificity of ultrasound descriptors helps reduce false positives and avoid overdiagnosis, while the sensitivity they contribute in conjunction with mammography improves early cancer detection rates.[12],[13],[14] Breast ultrasound also holds particular clinical significance in the evaluation of male patients. Clinically significant fibroglandular tissue in males most often presents as gynecomastia, typically a palpable, “flame-shaped” retroareolar focus of fibroglandular tissue.[13] Ultrasound plays a central role in differentiating gynecomastia from male breast carcinoma, especially in patients with risk factors such as hormonal therapy, chronic liver disease, or certain medications and illicit drug use. The characteristic imaging pattern of gynecomastia—a triangular or nodular area of increased echogenicity radiating from the nipple into the subareolar region—supports a benign diagnosis when correlated with clinical history. On the other hand, a unilateral, eccentric mass with irregular margins or associated skin or nipple changes may prompt a more aggressive diagnostic approach. Thus, ultrasound not only clarifies ambiguous physical findings in male patients but also guides appropriate triage and avoids unnecessary alarm when typical benign patterns are present. The completeness and clarity of the ultrasound report are crucial in transforming imaging findings into actionable clinical decisions. Key components of a high-quality breast ultrasound report include: a succinct yet informative statement of the indication; explicit comparison to prior imaging when available; detailed description of the technique used, including the scope of tissue examined and any special methods such as Doppler or 3D imaging; a brief summary of breast composition or background echotexture; and a precise description of each relevant finding, including its size, location, sonographic characteristics, and associated features.[12] The use of color or power Doppler, for instance, should be documented when it contributes to characterization, such as identifying vascularity in a solid mass or confirming the presence of thrombus or absent flow in superficial veins, as might be seen in entities like Mondor disease. The report must culminate in a clearly stated BI-RADS assessment category (0 or 1 through 6), followed by specific management recommendations, which may include routine screening, short-interval follow-up, targeted mammographic views, MRI, biopsy, or surgical consultation.

Ultrasound’s clinical significance also extends to its role in interventional procedures and therapy monitoring. Image-guided interventions, including core needle biopsy, vacuum-assisted excision, cyst aspiration, and preoperative localization, rely heavily on ultrasound’s ability to provide real-time visualization of both lesion and needle. This reduces the need for more invasive or less accessible guidance modalities and allows for precise sampling of suspicious areas, thereby improving diagnostic yield. Furthermore, in patients undergoing neoadjuvant chemotherapy, serial ultrasound examinations provide a noninvasive method for tracking tumor response, measuring changes in size and internal vascularity, and helping to refine surgical planning based on residual disease. In this way, ultrasound actively participates in personalized treatment strategies, enabling timely adjustment of medical or surgical approaches based on real-time imaging feedback. In sum, the clinical significance of breast ultrasound is multifaceted and profound. It enhances diagnostic accuracy through standardized descriptors and BI-RADS-based assessment, supports rational decision-making in the follow-up of benign and probably benign lesions, aids in the early detection and characterization of malignancies, and provides indispensable guidance for interventional procedures and treatment monitoring.[12–14] When coupled with meticulous technique, comprehensive reporting, and integration with other imaging modalities and clinical data, breast ultrasound stands as a cornerstone of contemporary breast care, contributing meaningfully to improved patient outcomes across a broad spectrum of clinical scenarios.

Enhancing Healthcare Team Outcomes

Enhancing healthcare team outcomes in the context of breast ultrasound requires a comprehensive, collaborative approach that integrates clinical expertise, technological proficiency, and effective communication among all members of the care team. Physicians, advanced practice providers, nurses, pharmacists, and allied health professionals must cultivate advanced skills in interpreting breast ultrasound findings, recognizing subtle imaging variations, and understanding the implications of evolving diagnostic techniques. Because breast imaging practices continue to advance rapidly, ongoing professional education is essential. This includes participation in continuing medical education (CME), hands-on workshops, simulation-based training, and interprofessional education (IPE) programs that expose healthcare professionals to the latest ultrasound technologies, such as elastography, Doppler imaging, and automated whole-breast ultrasound systems. The expanding role of point-of-care ultrasound (POCUS) across multiple medical specialties further underscores the need for clinicians to stay updated on best practices and evidence-based guidelines [14]. A key component of enhancing team outcomes is fostering effective communication. In breast health management, timely and accurate reporting of imaging findings is critical, but equally important is the exchange of insights and clinical impressions among team members. Radiologists must clearly convey results to referring clinicians, who in turn integrate these findings with clinical examination and patient history. Nurses and advanced practice providers contribute by educating patients, coordinating follow-up care, and ensuring adherence to recommended imaging intervals. Pharmacists may play an indirect yet important role by evaluating medication histories that could influence breast physiology, such as hormone therapies, chemotherapeutic agents, or drugs associated with gynecomastia. For the team to function optimally, all professionals must participate in open dialogue, share expertise, and express concerns when discrepancies arise. This communication framework also supports shared decision-making, ensuring that patients receive balanced, accurate information about diagnostic pathways and treatment options [14].

Equally important is the establishment of clearly defined roles within the interprofessional team. Role clarification allows each practitioner to understand their responsibilities and contributes to more efficient workflows, minimizing redundancy and reducing the likelihood of errors. Structured conflict resolution strategies should also be implemented, especially in academic or training environments where learners and seasoned practitioners frequently interact. Addressing disagreements constructively fosters mutual respect and promotes patient-centered decision-making [14]. Collaborative strategic planning plays a crucial role in aligning breast ultrasound practices across disciplines. Developing institution-wide or network-wide standardized protocols promotes consistency in breast imaging, from technique optimization to documentation standards and follow-up recommendations. Regular multidisciplinary meetings—such as tumor boards, imaging rounds, or quality improvement committees—provide structured opportunities to update guidelines, review complex cases, and incorporate new evidence into practice. Such forums drive alignment between radiologists, surgeons, oncologists, and primary care providers, ensuring that patient care pathways remain cohesive and grounded in current scientific knowledge. Furthermore, integrating breast ultrasound within broader care pathways ensures a streamlined patient experience. A patient's progression from screening to diagnosis and treatment should occur seamlessly, facilitated by coordination among clinicians, schedulers, and support staff. Interoperable electronic health record systems, shared imaging databases, and standardized reporting models also enable efficient information exchange, reducing delays and preventing miscommunication. This integrated approach ensures that abnormalities detected on ultrasound are promptly correlated with mammography, MRI, or biopsy results and that patients receive timely guidance on next steps [14]. Ultimately, healthcare professionals who collaborate effectively, communicate openly, and engage in continuous learning significantly enhance patient-centered care in breast imaging. By working together to interpret complex ultrasound findings, apply evidence-based practices, and guide patients through diagnostic and therapeutic pathways, interprofessional teams can improve diagnostic accuracy, optimize treatment outcomes, ensure patient safety, and elevate overall team performance. In this way, breast ultrasound becomes not only a diagnostic tool but also a platform for interdisciplinary excellence that strengthens the entire continuum of breast healthcare.

Nursing, Allied Health, and Interprofessional Team Monitoring

Effective monitoring of nursing, allied health, and interprofessional team engagement in breast ultrasound education is essential to promoting consistent, high-quality patient care. Interprofessional Education (IPE) serves as a cornerstone of this collaborative model, ensuring that each member of the healthcare team gains both the technical proficiency and communication skills necessary for coordinated breast imaging practices. Pre-workshop assessments play a crucial role in establishing baseline measures of participants' demographics, prior exposure to breast imaging, and attitudes toward interprofessional learning. These assessments not only help educators tailor content to the needs and experience levels of attendees but also highlight existing gaps in knowledge and perceptions that may influence the success of training initiatives. Understanding attitudes toward IPE prior to instruction can also illuminate potential barriers, such as hierarchical dynamics, unfamiliarity with team-based learning, or discrepancies in professional roles that may affect engagement during breast ultrasound training (see Image. Interprofessional Education in Breast Ultrasound) [15]. During training sessions and collaborative teaching events, simulation-based activities serve as powerful tools for enhancing awareness and interest in ultrasound imaging. Hands-on practice with phantoms, live demonstrations, or guided scanning exercises allows participants—including nurses, sonographers, advanced practice providers, and other allied health professionals—to develop confidence in image acquisition and interpretation. Simulations also provide a controlled environment for practicing communication, shared decision-making, and real-time problem-solving. These practical experiences reinforce the importance of coordinated teamwork, especially when evaluating breast findings, navigating complex diagnostic scenarios, or preparing for ultrasound-guided interventions. Moreover, collaborative simulations help dismantle discipline-specific silos, encouraging participants to appreciate the complementary roles that each profession brings to breast care.

Following the integration of workshop content into clinical practice, follow-up monitoring is an essential component of evaluating the long-term effectiveness of IPE initiatives. Post-training surveys or structured feedback sessions allow educators to assess whether changes in attitudes toward interprofessional collaboration have occurred and whether participants perceive improvements in contextual learning across medical disciplines. Monitoring outcomes may include increased confidence in performing or assisting with breast ultrasound, greater adherence to standardized protocols, improved communication among team members, and enhanced patient education during imaging encounters. These outcomes not only reflect individual professional growth but also demonstrate broader improvements in team functioning, workflow efficiency, and diagnostic accuracy [15]. Longitudinal monitoring further contributes to sustainability, ensuring that initial enthusiasm generated during training translates into meaningful practice changes. Regular re-evaluation allows program leaders to refine future workshops, address persisting challenges, and integrate emerging technologies or updated guidelines into the curriculum. Ultimately, systematic monitoring of nursing, allied health, and interprofessional participation helps cement IPE as a continuous, evolving process that strengthens the entire breast healthcare team. By fostering mutual respect, shared knowledge, and coordinated care strategies, healthcare professionals across disciplines become better equipped to support patients through all stages of breast imaging and management [15].

Conclusion:

In conclusion, breast ultrasound stands as a cornerstone of contemporary breast care, far surpassing its traditional role as a simple problem-solving tool. Its clinical significance is profound and multifaceted. It is critical for the early detection and characterization of malignancies, particularly in women with dense breast tissue where mammography has limitations. The standardized BI-RADS lexicon provides a essential framework for consistent interpretation, communication, and risk stratification, directly guiding management pathways from routine surveillance to urgent biopsy. Furthermore, ultrasound's utility extends into interventional procedures, offering real-time guidance for biopsies and localizations, and into therapy monitoring, allowing for non-invasive tracking of treatment response. Ultimately, the full potential of breast ultrasound is realized through a collaborative, interprofessional approach. Effective integration of this modality into patient care requires skilled sonographers and radiologists, clear communication among all healthcare team members, and meticulous, standardized reporting. When combined with other imaging modalities and clinical data, breast ultrasound significantly enhances diagnostic accuracy, optimizes treatment planning, and improves overall patient outcomes across a wide spectrum of breast conditions.

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