Chapter

# Value of Breast Ultrasound in the Clinical Practice of the Surgeon

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## Abstract

In recent years, breast surgeons have been increasing the use of ultrasound as a reliable and useful tool in their practice to assist in managing patients and the operating room. An appropriate clinical and sonographic correlation can define diagnostic workup, provide immediate reassurance to the patients, and perform one-site diagnostic needle interventions. Particularly, it has a significant role in low-middle income countries, where imaging services are scarce due to its high cost, maintenance needs, and limited availability of trained personnel. Therefore, training and accreditation of surgeons who perform and interpret ultrasound are required interventions to influence the provider's knowledge, accomplish optimal practices, complete diagnostic examinations of the breast, and improve the patients' quality of care. This review aims to serve as an educational resource regarding the up-to-date value of breast ultrasound for surgeons.

**Keywords:** Breast Ultrasound, Breast Imaging, Interventional Radiology, Breast Cancer, Intraoperative Ultrasound, Low and Middle Income Countries, Breast Surgeon

## 1. Introduction

Ultrasound (US) is a reliable and helpful tool in evaluating, diagnosing, and managing breast disease improving the patients' quality of care. In recent years, with the increasing quality of the ultrasonography equipment, the surgeons have escalated its use, particularly by breast surgeons in their clinical practice and operating room, which has led to the enhanced provision of care for women with breast disease [1, 2].

Breast ultrasound allows immediate identification and characterization of localized breast symptoms, palpable abnormalities noted on physical breast examination; and nonpalpable abnormalities identified on other breast imaging modalities. Hence, an appropriate clinical and sonographic correlation can define diagnostic workup, provide immediate reassurance to the patients, and perform one-site diagnostic needle interventions. In addition, it has the advantages of being low-cost, more affordable, portable, safe, and requires minimal maintenance. It has a significant role in low-middle income countries, where imaging services are scarce due to its high cost and limited availability of trained personnel [3]. In these settings, capacities on local referral chains are minimal; therefore, the use of US by breast surgeons offers significant appropriateness to the patients by allowing them to obviate the high threshold needed to reach referral services.

Breast surgeons can acquire comprehensive skills and competence in US techniques and their indications in the outpatient setting under the supervision of a

US-experienced radiologist or surgeon, enhancing the multidisciplinary care of breast patients. Also, participation in training courses guided by local proficiency standards [1] allows the successful incorporation of breast ultrasound and ultrasound-guided breast procedures into clinical practice, which can then be translated into the operation room. Training and accreditation of surgeons who perform and interpret ultrasound is an intervention that influences providers' behavior for optimal patient outcomes. Hence, the surgeon who assists in managing breast patients has to design a rational plan of action based on their knowledge, available resources, and patient needs to ensure adequate and safe breast care [4–6].

The purpose of this review is to serve as an educational resource for the value of breast ultrasound in the clinical practice of the surgeon by providing the understanding of its applications for the evaluation, management, and monitoring of breast diseases; and the recognizing of its indications for interventional breast procedures in order to improve the decision-making process and enhance patient care.

## 2. Indications of breast ultrasound

Breast ultrasound is valuable in several clinical situations, including but not limited to the following [4, 5, 7]:

- Identification and characterization of localized breast symptoms, palpable abnormalities noted on clinical breast examination, and nonpalpable abnormalities identified on other breast imaging modalities.
- Initial Imaging evaluation of localized breast symptoms and palpable abnormalities in patients under 40 years of age who are not at risk of developing breast cancer and in lactating or pregnant women.
- Evaluation and characterization of abnormalities associated with breast implants.
- Guidance for breast interventional or surgical procedures.
- Preoperative evaluation of the breast and axilla in diagnosed breast cancer.
- Evaluation and assessment of the breast after surgical or medical therapy.
- Intraoperative ultrasound-guided breast surgery and intraoperative assessment of lumpectomy margins.

## 3. Breast ultrasound overview

Breast Ultrasound is a diagnostic tool that makes the whole imaging assessment more specific and expedited. Alongside clinical information, US characterization allows imaging correlation to define further imaging workup and recommend interventional procedures for diagnostic and therapeutic purposes. Ultrasound is called hand-held or manual when the probe is manually moved on the breast surface (HHUS). In automated whole breast ultrasonography (ABUS), the probe scans the whole breast in a standard fashion, gathering and storing a set of images for later review by physicians interpreting the findings [8].

### 3.1 Reporting system

The Breast Imaging Reporting and Data System® (BI-RADS®) is a management system developed for imaging that contains: (1) a lexicon of descriptors, i.e., a dictionary of specific imaging features; (2) a standardized reporting structure-including final assessment categories with accompanying recommendations; (3) a framework for data collection and auditing. This system aids communication and comprehension of imaging findings by all members of the multidisciplinary breast care team: surgeons, pathologists, oncologists, radiologists, and other health care providers. BI-RADS final assessment categories and their recommendations have become the standard by which physicians determine breast care, allowing uniform drafting of reports, facilitating the research, and performance evaluation [9].

These categories, currently are as follows [10]:

- Category 0: Incomplete. Need additional imaging evaluation or previous images for comparison to determine appropriate management and final assessment.

- Category 1: Negative. There is no US imaging abnormality. Routine screening.

- Category 2: Benign Findings. Negative for malignancy. No further investigation is required based on the imaging finding. Routine screening.

- Category 3: Indeterminate/Probably Benign Finding. Lesions with less than 2% risk of malignancy. Should recommend initial short-interval follow-up.

- Category 4: Suspicious Abnormality. Lesions with >2% but <95% likelihood of malignancy. Diagnostic tissue sampling through biopsy should be performed in the absence of clinical contraindication— 4A (low suspicion for malignancy, >2% but ≤10% likelihood of malignancy), 4B (moderate suspicion for malignancy, >10% but ≥50% likelihood of malignancy), and 4C (high suspicion for malignancy, >50% but <95% likelihood of malignancy).

- Category 5: US findings highly suggestive of malignancy. More than 95% likelihood of malignancy. Diagnostic tissue sampling through biopsy should be performed in the absence of clinical contraindication.

- Category 6: Known biopsy-proven malignancy. Reserved for US examinations performed for cancer staging or monitoring of neoadjuvant therapy.

Similarly, in the UK, the Royal College of Radiologists Breast Group (RCRBG) [11] has developed a five-point scoring system to classify breast images, using a similar rationale to the American College of Radiologists' development of the BI-RADS®. However, this classification does not specify the probable cancer risk of each category. This five-point system is Normal (category 1)- there are no significant imaging findings. Benign findings (category 2)- the benign imaging findings are not indicated for further investigation. Indeterminate / probably benign (category 3)- low risk of malignancy, and further investigation through needle biopsy is indicated. Findings suspicious of malignancy (category 4)- show a moderate risk of malignancy, so further investigation is indicated through a needle biopsy. Highly suspicious findings of malignancy (category 5)- high risk of malignancy; further investigation is indicated through a needle biopsy.

### 3.2 Imaging quality

The US is a highly operator-dependent technique due to a lack of repetitiveness and a strong reliance on specialists' abilities and judgment to capture the right image to be documented in the report. Although the ACRIN 6666 trial has proposed a model, no standard US acquisition technique exists yet [12]. A specialist with competence and experience should perform breast ultrasound [13, 14], correlating clinical signs or symptoms, mammographic studies, and other breast imaging. If the ultrasound has been performed previously, the current examination should be compared with a previous ultrasound, as appropriate.

### 3.3 Setting

The correct application of the vocabulary depends on the quality of the ultrasound equipment, ultrasound technique, and an adequate compression of the breast anatomy. Breast ultrasound should be performed with high-resolution linear array transducers from 7.5–8 (at least) to 15–18 MHz. Higher frequency is recommended for less depth penetration (superficial details or small breasts). Lower frequency should be used for deeper areas or very large breasts (4 to 8 MHz) [5]. An acoustic stand-off pad is useful for superficial images. It is critical to document and capture appropriate imaging for actionable cases by optimizing focal zone selections, gain settings, and view fields. When a potential finding is located, turn the transducer to assess if it persists and better characterize it. A wide-band linear matrix transducer offers better resolution by focusing on the short axis.

### 3.4 Positioning

The patient should be lying in the supine position placed with the chest undressed. There are two breast survey patient positions: a medial position with the ipsilateral arm overhead or with arms flexed behind the head to flatten the breast, and an oblique position with a wedge supporting the back for scanning the lateral part of the breast and the axilla. Scan techniques should allow systematic exploration of the entire breast, whether grid scanning or radial scanning patterns.

### 3.5 Labeling

Images should be labeled as right or left breast and should be reported the transducer orientation. The localization of the findings is described by quadrant -upper external, lower external, lower internal, upper internal- and retroareolar region; or according to the clock-wise position (distance from the nipple). Distance from the nipple to the lesion should not be measured from the areola's edge since the areolar width is variable [5]. A large lesion can be captured in a single image by Panoramic Imaging (Extended Field of View –FOV-) and traced the lesion back to the nipple for an accurate distance reporting.

### 3.6 Measurements

All lesions are measured in three dimensions, including length, width, and height unless shadowing disguises the accurate height measurement. Dimensions must register with the greatest millimeter or centimeter accuracy. The first measurement represents the longest axis. The following measurement is perpendicular to the long axis, and the last measurement is from an orthogonal projection to the first image (representing a different plane from the former two images). It is necessary to capture two sets of lesion images (one with calipers and one without) [6, 10].

Solid masses diagnosed as benign pathology may safely have periodic surveillance if the volume growth rate is less than 16% per month in women under 50 years and less than 13% per month in women 50 years or older. An acceptable mean change for three dimensions during a six-month interval is 20% for all ages [15].

### 3.7 Documentation

Accurate documentation is essential for high-quality patient care. Ultrasound report is only as good as the images on which it is based. Images and reports are part of the patient's medical record. Each image should have the facility name, date of examination, patient's first and last name, identification number, and birth date. It should display identification of left or right breast and lesion's location. It should indicate transducer orientation within the breast (radial, antiradial, oblique, transversal, or sagittal), distance from the nipple, and three orthogonal measurements. Breast ultrasound document must contain the following sections [5, 6, 10]:

- Indication of breast ultrasound.
- Description of the scope and technique of breast ultrasound.
- Brief description of the overall composition of the breasts.
- A detailed description of important findings.
- Comparison with prior relevant imaging studies and correlation with signs observed during the clinical examination.
- Assessment and management recommendations.
- Report of ultrasound-guided interventional procedures should include the location of the lesion, the approach, the type of prep and local anesthesia, the skin incision, the type of device used, the number of cores taken, and the type of clip placed, if any. Whenever specimen radiographs or sonograms are performed, they should be recorded in the report.

## 4. Breast ultrasound lexicon

Descriptors for breast tissue composition (background echotexture) are correlated to mammographic breast densities. These are homogeneous-fat, homogenous-fibroglandular, and heterogeneous. In Homogeneous-fat background, fat lobules and echogenic bands of supporting structures comprise the bulk of the breast tissue. In the Homogeneous-fibroglandular background, a dense zone of the homogeneously echogenic bands of fibroglandular parenchyma is present beneath the thin hypoechogenic layer of fat lobules. Heterogeneous background echotexture is characterized by multiple small areas of increased or decreased echogenicity, either focal or diffuse.

For the identification and characterization of the masses, the number of characteristics to be described are seven: *shape* (oval, round, and irregular), *orientation* (parallel and not parallel), *margins* (circumscribed and not circumscribed, indistinct, angular, microlobulated, and spiculated), *echo pattern* (anechoic, hyperechoic, complex cystic and solid, hypoechoic, isoechoic and heterogeneous) *posterior acoustic features* (no posterior acoustic features, enhancement, shadowing and combined pattern), *calcifications* (in or outside of a mass, and intraductal) and *associated features*.

Associated features include architectural distortion; edema; duct changes; skin changes (skin retraction, skin thickening-focal and diffuse-); vascularity (absent, internal, and vessel in rim), and elasticity assessment. Elasticity assessment of tissue stiffness (elastography) explores modifications of the US image of a lesion after applying a manual compression (strain) or introducing ultrasonic energy (shear wave). Applicable descriptors are color-codes tissue hardness. The elasticity assessment is a feature available on many modern US units and included in the last BI-RADS edition. The World Federation of Ultrasound in Medicine and Biology (WFUMB) has published guidelines in characterizing breast lesions as benign or malignant, although this fact cannot be misinterpreted as an entire endorsement of the clinical validity of elasticity assessment. Therefore, the elastography should be integrated for patient management alongside the more predictive ultrasonic morphologic features of malignancy (shape, margin, and echogenicity). Currently, the share-wave elastography is used as a valuable preoperative predictor of chemotherapy response [16].

It is essential to analyze several features, rather than just one, for lesion categorization as benign or malignant. Benign and malignant solid masses can equally be well-differentiated on ultrasound. Benign US features include an oval shape, well-circumscribed margins, and parallel orientation to the skin. Suspicious US features include irregular margins, marked hypoechogenicity, post-acoustic shadowing, and non-parallel orientation to the skin (**Figure 1**).

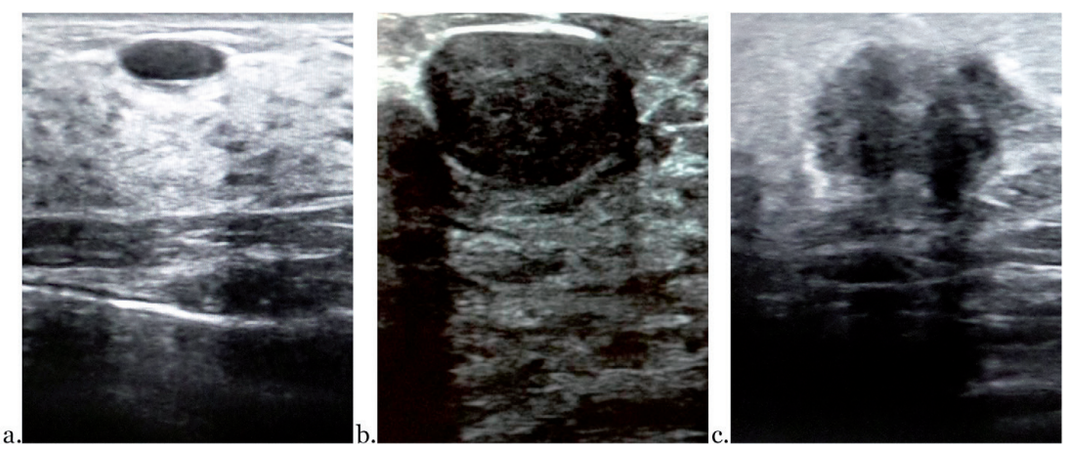


**Figure 1.**
*Ultrasound characteristics of breast lesions. (a) Circumscribed, oval, anechoic mass with parallel orientation and posterior enhancement consistent with a simple cyst. (b) Circumscribed, round, heterogeneous mass with lateral shadowing. The pathological diagnosis by biopsy was Fibroadenoma. (c) Irregular, noncircumscribed, hypoechoic mass with posterior shadowing: Invasive Breast Carcinoma by biopsy.*

## 5. Identification and characterization of palpable breast symptoms

### 5.1 Nipple discharge

Clinical workup of nipple discharge includes a detailed patient medical history, recently recorded trauma, careful physical examination, and the most suitable breast imaging modality. The evaluation and management aim of nipple discharge is to identify the causative condition accurately, distinguishing between "pathologic" causes from those with "benign or physiological" causes, and consequently diagnosing cancer when it is present.

The discharge's clinical characteristics should describe color, whether uni or bilateral or associated with nipple stimulation or breast compression, whether it originated from a single duct or multiple ducts [17]. Benign nipple discharge is traditionally considered bilateral, non-spontaneous, emanating from multiple ducts

after manipulation or stimulation; varies in color from white to yellow to green to brown. Pathologic discharge is considered unilateral, spontaneous, persistent, clear, serous, serosanguinous, or bloody from a single duct [18].

Breast imaging identifies and characterizes any lesion in these patients and assists subsequent percutaneous biopsy in achieving a histopathologic diagnosis [19]. Magnetic resonance imaging (MRI) may be useful in pathologic nipple discharge when lesions cannot be localized with other diagnostic imaging [20]. However, MRI is limited, and it is not yet a generalized practice because it is expensive and not readily available in all areas [21].

In patients with nipple discharge, the sensitivity of mammography in detecting an abnormality is low. The ability of mammograms to identify intraductal lesions is limited since they are generally small and lack microcalcifications. In mammography subareolar region usually shows increased density. The sensitivity and specificity of ultrasound vary from 36 to 83% and 12–84%, respectively. Several factors can explain this wide range, including differences in the criteria used to distinguish between pathologic from benign discharge and differences in ultrasound technology employed [22]. Breast US is useful for visualizing ductal structures, localization of the lesions that cause the nipple discharge, and the subsequent accomplishment of imaging-guided percutaneous biopsy to determine whether a malignant lesion is the cause of the pathologic nipple discharge. US-guided core needle biopsy in patients with pathologic nipple discharge, who had negative findings on mammography but had positive findings on US have reported 15.1% of cancer detection [23].

Breast US is capable of visualizing ductal structures located in the subareolar region. The BI-RADS® categorizes ductal changes as *associated features*. Duct changes are manifested by:

- cystic dilatation of a duct or ducts comprising irregular calibers or arborization. Dilated retroareolar duct is defined as duct ectasia, i.e., a duct with a diameter over 3 mm;

- extension of ducts to or from a malignant lesion; or

- intraductal mass, thrombus, or debris. Intraductal masses are assessed as category 4a, pointing out a requirement for biopsy because these have a risk of malignancy that cannot eliminate (**Figure 2**) [10, 24].

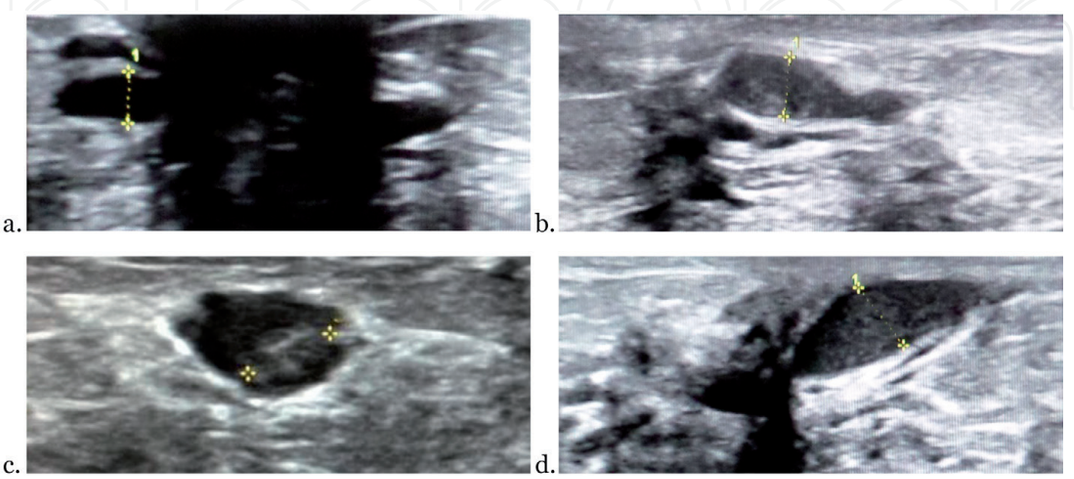


**Figure 2.**
*(a) Single galactophere duct ectasia without any filling defect (calipers); (b) 49-year-old female with uniorificial serous nipple discharge. US: duct ectasia with echogenic content filled with thick secretion; (c) 46-year-old female with uniorificial bloody nipple discharge. US: single dilated duct with isoechoic endoductal mass with an ill-defined outline representing an intraductal papilloma by pathology report; (d) 39-year-old female with right uniorifical serosanguineous discharge. US: irregular intraductal mass arising from a dilated duct due to carcinoma in situ.*

At present, there are no clear guidelines on which radiographic or clinical variables in patients with nipple discharge can predict malignancy. The malignancy rate in patients with nipple discharge ranges from 9.3–23% [18, 25–29]. However, these data were derived from studies made before improvements in breast ultrasound and the imaging-guided percutaneous biopsy. Most studies included patients referred to surgery departments or specialty breast centers [18, 25–27] or only those who underwent duct excision [28, 29].

Currently, less invasive diagnostic procedures affect the decision-making process about surgical management. For patients with pathological discharge and negative imaging evaluation (negative mammography results and negative features on breast US), surgical treatment has traditionally been indicated to eliminate symptoms and rule out breast carcinoma [24–28]. Although based on the low risk of underlying carcinoma, several studies have proposed conservative clinical follow-up and have shown that short-term monitoring would appear to be a reasonable approach in these patients [30, 31] Sabel et al. [31] suggested short-term observation with repeat imaging and clinical exam for low-risk patients (those without a strong family history or personal history of cancer). Ashfaq et al. [30] proposed a close clinical follow-up comprising a physical examination and breast ultrasound every six months for 1 to 2 years, or until the discharge resolved, whichever came first, plus annual mammography according to the screening guidelines. Patients who refuse to watch and wait as a clinical approach or report discomfort by the symptom or discharge after two years should consider the surgical treatment (**Figure 3**).

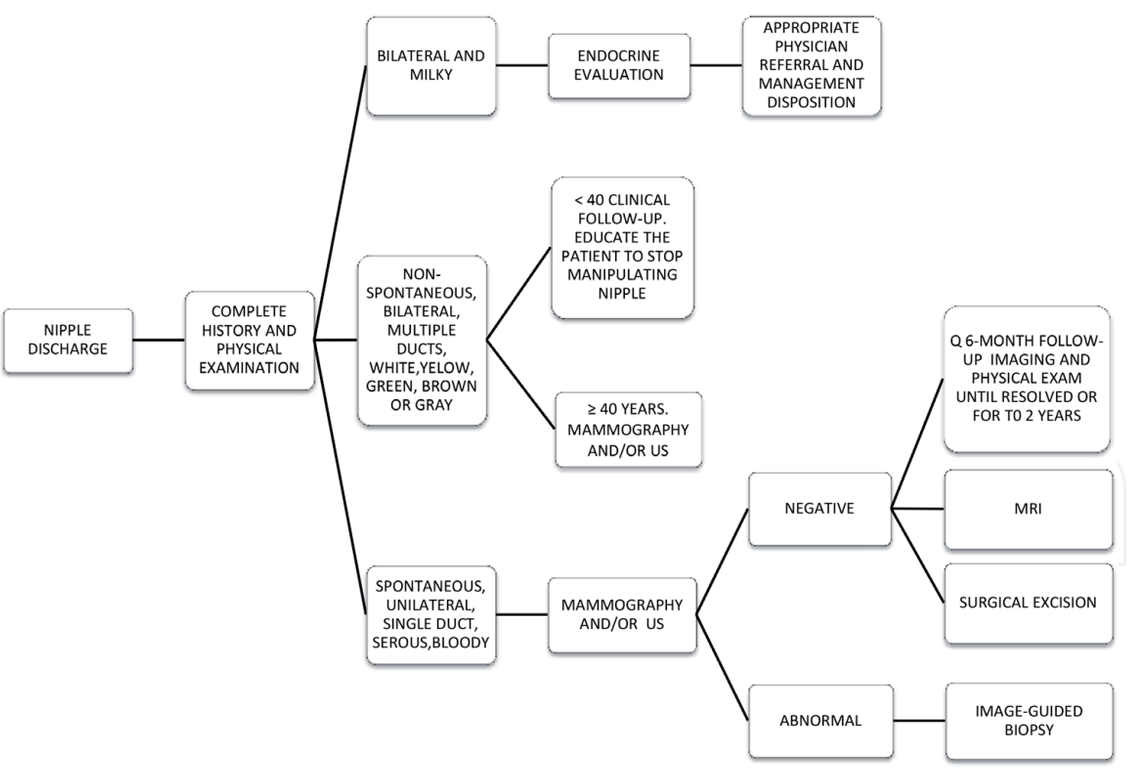


**Figure 3.**
*Workflow for the management of women presenting with nipple discharge.*

## 5.2 Inflammatory breast disease

Ultrasound examination is essential in evaluating patients with breast inflammation to identify fluid collections in the affected area by the inflammatory

process and distinguish between cancer-related and non-cancer-related breast inflammation (since their clinical presentation can be misleading). Inflammatory breast disease manifests clinically by the cardinal signs of inflammation: redness, heat, and pain. It is classified as an infectious origin (generally bacterial) or non-infectious origin.

Breast US cardinal signs of infectious inflammatory breast disease are [32]:

- Skin thickening.
- Reticulated network of irregular hypoechoic lines, located at the interface between the dermis and subcutaneous fat, representing either dilated lymphatics or interstitial fluid.
- Increased echogenicity of surrounding fat tissue. Hyperechoic area extension is variable and depends on the degree of inflammation.
- Subcutaneous dilated vessels. Doppler signal demonstrates increased vascularity associated with hyperemia.
- Reactive lymphadenopathy: Enlarged axillary lymph nodes, regular cortical thickening, smooth borders, and visible central hilum.
- Ductal ectasia with thickened walls and echoic content into the duct (Galactophoritis).
- Breast abscess presents as round, oval or irregular; generally hypoechoic with multiples internal echoes, sometimes with fluid-debris level; usually with posterior acoustic enhancement. The walls may appear thickened with indistinct margins to the surrounding hyperechoic fat. An evident hypoechoic sinus tract probably extends the skin surface (Zuska's disease) [33]. It is a rare disease characterized by repeated and recurrent episodes of inflammatory abscesses and fistulae that is usually open on the edge of the areola or in the breast tissue close to it.

Ultrasound can be used to guide percutaneous sampling procedures and complete drainage of the fluid collection. If the collection is large (sizes >3 cm)- or if it remains or recurs-placing a percutaneous drainage catheter guided by US is the optimal course of the management [34]. In the unusual event of inadequate percutaneous drainage, surgical drainage should be an option.

Non-infectious inflammatory breast disease includes Granulomatous Mastitis and Diabetic Mastopathy. Diabetic Mastopathy appears as a hypoechoic mass with ill-defined margins and marked posterior shadowing.

Granulomatous Mastitis is a diagnosis of exclusion, and it is hardly made based on clinical signs and imaging findings. Clinical presentation is a firm to hard mass localized or diffused involvement of the entire breast with skin thickening, erythema, and inflammation (peau d' orange) that can clinically mimic carcinoma. In addition, the presence of draining sinus tracts and regional adenopathy are frequent. The diagnosis is established by histological analysis showing a granulomatous inflammatory response containing multinucleated giant cell granuloma. It is mainly seen in developing countries [35, 36]. Breast US signs in granulomatous mastitis are:

- Skin thickening

- Heterogeneously hypoechoic mass with poorly defined borders, with internal tubular hypoechoic structures.

- Parenchymal heterogeneity and architectural distortion with or without acoustic shadowing in the absence of a definite mass. Increased surrounding parenchymal vascularity on Doppler ultrasound.

- Enlarged axillary lymph nodes with reactive cortical thickening.

- Fluid collections with low-level internal echoes and hypoechoic sinus tracts extending to the skin in advanced cases (**Figure 4**).

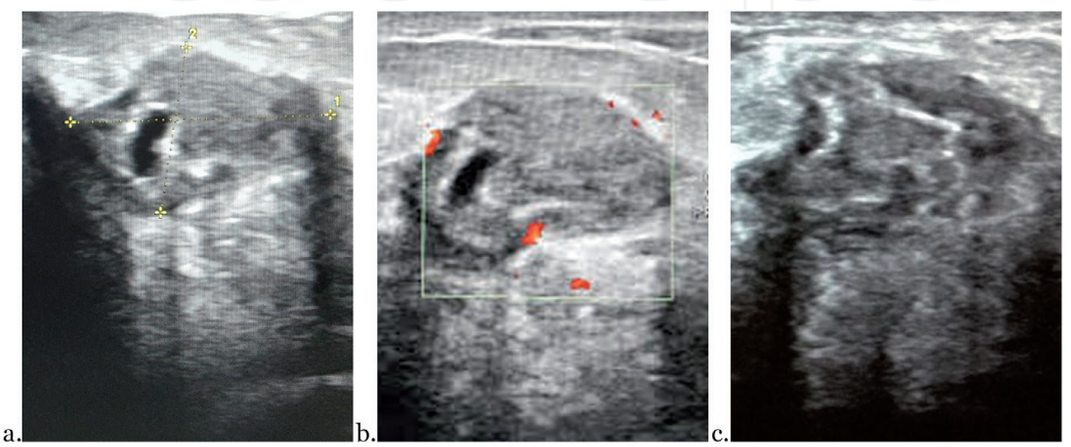


**Figure 4.**
*45-year-old female with redness, heat, and pain in the right breast. US: (a) Hypoechoic mass with heterogeneous content, poorly defined borders, and acoustic shadowing. Thickening of the dermal layer. Fat hyperechogenicity around the mass. (b) Image using Doppler signal reveals increased surrounding vascularization. (c) US-Guided Percutaneous Biopsy: Granulomatous Mastitis.*

### 5.3 Mass in breast skin

Lesions in the breast skin that arise within the dermal layer are considered generally benign. Most dermal lesions are palpable, providing the reason for imaging evaluations. Although occasionally, they are detected at screening imaging. This lesion includes dermal cysts, specifically sebaceous cysts and epidermal inclusion cysts (after a mammoplasty), for which routine surveillance is recommended..

Ultrasound findings of dermal lesions are [37]:

- An echogenic dermal layer surrounds lesions.

- A tract-to-skin from the lesion represents an extension of the hair follicle from the dermis through the epidermis.

- An acute or right angle (90 degrees) with the dermal line. A claw of hyperechoic tissue wraps around the lesion's margin.

- Round well-circumscribed nodule or non-circumscribed-when inflammation is present-depending on its contents. The internal echotexture varies from anechoic to hypoechoic and heterogeneous (**Figure 5**).

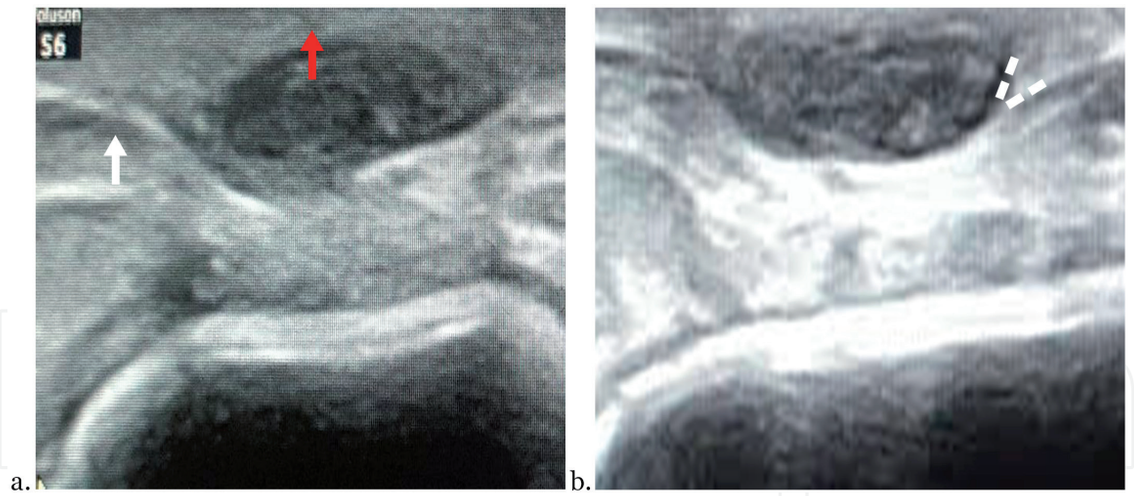


**Figure 5.**
*57-year-old female with epidermal inclusion cyst located on the breast skin after mammoplasty. US: (a) hypoechoic well-circumscribed mass contained within the dermis. The dermal layer is thickened (white arrow) and extended into the hypodermis. A tract extends to the epidermal skin surface (red arrow). (b) The claw sign (white dashed line): dermal tissue wrapping around the margin of the lesion forming an acute angle.*

## 6. Evaluation and characterization of abnormals associated with implants

In addition to the clinical examination, ultrasound is a useful diagnostic test to examine breast implant alterations, mainly ruptures. The breast implant is anechoic with an echogenic shell of a three-layered appearance (an anechogenic line between two echogenic lines). Small radial folds and a small amount of periprosthetic fluid are considered normal findings. US is very specific in evaluating breast implant integrity, albeit not very sensitive. The probability of rupture is highly suspected in US, but a rupture is still possible, even if it cannot be visible in US [7].

Alterations of the implant structure, classically, are *capsular contracture* or *capsular fibrosis* and *ruptures*. Capsular contracture is the capsule developed around the implant as the body's overreaction to a foreign device, leading to the hardening and deformation of the implant. There are three typical findings for capsular contracture or fibrosis: (1) *deformity*, not well evaluable with ultrasound (due to the narrow field of view), (2) *increased number of radial folds,* creating an undulated implant surface; and (3) *thickening of the fibrous capsule*, an echogenic line superficial to the implant shell, separated only by an anechoic line [38].

*Ruptures* are subdivided into intracapsular (implant envelope is broken, but containment remains inside the capsule) and extracapsular (when containment leaks out of the broken capsule) type [39]. The classic finding of extracapsular rupture of silicone implant on US is the snowstorm appearance, i.e., a highly echogenic pattern of scattered and reverberating echoes with a well-defined anterior margin. This appearance can also see in the axillary nodes containing free silicone. Intracapsular silicone implant rupture finding is the stepladder sign, characterized as a sequence of horizontal echogenic straight or curvilinear lines inside the collapsed implant shell [40]. If the prosthesis is saline, the collapsed implant shell will be evident by ultrasound.

According to the American College of Radiologists [41], breast implants evaluation varies on patient age, implant type, and symptoms. For patients less than 30 years with rupture of saline implants, ultrasound is the imaging choice. Mammography or US may be used for patients from 30 to 39 years of age with rupture of saline implants, and mammography is preferred for those 40 years and older. MRI without contrast or US is preferred for patients less than 30 years with

rupture of silicone implants. MRI without contrast, mammography, or US may be used for those 30 to 39 years of age, and for those 40 years and older, MRI without contrast or mammography is used. Patients with unexplained axillary lymphadenopathy and silicone implants (current or previous) are assessed with the axillary US. Patients with suspected breast implant-associated anaplastic large-cell lymphoma should be recommended breast US, regardless of age or implant type.

## 7. Guidance for percutaneous and interventional procedures

Interventional breast procedures are guided by the clinical examination or image-detected nonpalpable breast abnormalities to characterize the lesion histologically and plan therapeutic management [11]. Clinical guidance may be sufficient in palpable lesions, but image-guided biopsy allows more precise acquisition with high diagnostic accuracy. Ultrasound-guided procedures are accessible without needing ionizing radiation or intravenous contrast but are rather minimally invasive and less expensive than surgical biopsies [42].

Training and accreditation of surgeon-performed US are essential steps for increasing the use of percutaneous biopsy to diagnose breast pathologies, avoiding additional surgeries and diagnostic delays, particularly in resource constraint settings. Breast surgeons, who perform the percutaneous biopsy, must understand its indications, have technical skills for performing them, and be experienced operators to avoid misleading and harmful procedures, resulting in missed cancer. They should record complications and adverse events during ultrasound-guided interventional procedures and regularly review them to recognize circumstances and opportunities to improve patient management quality. In the same way, surgeons should monitor false-negative rates and inadequate tissue samples of these interventional procedures to audit their practice [9].

US-Guided interventional procedures include fine-needle aspiration cytology (PAAF), core needle biopsy (CNB), vacuum-assisted needle biopsy, placement of brachytherapy devices, and breast tissue ablation.

### 7.1 US-guided fine-needle aspiration cytology (US-FNAC)

FNAC uses a disposable needle (usually 18 to 27- gauge) connected to a vacuum syringe. It is technically simple, widely available, and easy to plan in outpatient clinics. It can be performed with a low risk of complications. It is an accurate technique and affordable in resource constraints settings [43]. Quality depends on the aspirator's competence and the pathologist's proficiency and expertise in determining its interpretation. FNAC is more appropriate for patients on anticoagulants for lesions adjacent to the skin, close to the chest wall or close to vessels, or patients with implants, or with very small lesions and those with small/thin breasts [44].

Ultrasound-guided needle aspiration puncture is mainly recommended for the aspiration of simple symptomatic cysts. If the aspiration fluid is clear, yellow, greenish-black (no atypical features), it can be discarded and not require further evaluation [45]. In case that the fluid is bloody, it must be sent for cytological analysis. If it looked purulent, it must be sent for culture and gram stain. If suspicious, atypical, or mucin results are found in cytology, re-biopsy or excision of the lesion should be performed. The patient should accomplish a follow-up ultrasound in 4 to 6 weeks when the cyst has been completely evacuated. Whether the cyst recurs, the re-biopsy of the lesion is mandatory [46].

Although core needle biopsy is currently advocated as the standard procedure in most breast centers in developed countries, FNAC continues to be an acceptable

and reliable procedure for diagnosing suspicious breast lesions in low and middle-income countries. Two meta-analyses assessed the accuracy performance of FNAC [46, 47]. The meta-analysis of Yu et al. [48] included 46 studies showing pooled sensitivity of 92.7% and specificity of 94.8%; however, the pooled sensitivity and specificity for eleven studies that reported unsatisfactory samples was 92.0% and 76.8%, respectively. The meta-analysis by Wang et al., [47] compared the sensitivity and specificity of CNB and FNAC in twelve studies; the pooled analysis showed that the sensitivity of CNB is better than that of FNAC (87% vs. 74%). However, the specificity of CNB was similar to that of FNAC (98% vs. 96%).

### 7.2 Ultrasound-guided core needle biopsy (CB)

Ultrasound-Guided Core Needle Biopsy involves 14G–16G spring-loaded automated needles with an excursion throw that allows small cylinders of tissue (specimen) to be cut and collected within the notch of the needle. The needle is extracted from the breast to recover the breast tissue and then re-inserted for further samples. False-negative rates range from 0% [49] to 9% [50], and underestimation rates range from 3.4–100% in atypical ductal hyperplasia, radial scars, papillary lesions, lobular carcinoma in situ (LCIS), and phyllodes tumors [51].

### 7.3 US vacuum-assisted biopsy (VAB)

VAB is commanded with suction and a rotating cutter. This device uses needles ranging from 7 G to 12 G. Vacuum aspiration pulls lesion tissue samples for collection into a sampling window without removing the needle from the biopsy site [50]. VAB is commanded with suction and a rotating cutter. This device uses needles ranging from 7 G to 12 G.

Currently, there is an increasing interest in using US-guided vacuum-assisted devices for the complete removal of a probably benign lesion [52, 53], with low rates of residual masses, particularly for lesions <1 cm in size [54]. Additionally, successful excision of intraductal masses has been reported in women with nipple discharge [55].

### 7.4 Guided ablative techniques

Tumor destruction techniques are by heat (hyperthermia) or by cold (cryotherapy) means. Several technologies using hyperthermia are available: radiofrequency, microwaves, interstitial laser, and electroporation [42]. The percutaneous radiofrequency device utilizes five small radiofrequency-enabled wires deploy from the wand (capture basket) to circumscribe the lesion. Radiofrequency passes through the expanded basket, sectioning and coagulating the breast tissue. The device can remove entire lesions up to 25–30 mm [56].

Cryotherapy involves the use of argon gas to generate an ice sphere around the lesion. Ultrasound is used in real-time to visualize the growth of the ice ball around the lesion; this is an outpatient procedure that can be performed under local anesthesia [2].

### 7.5 Indications for excisional biopsy

Currently, the percutaneous imaging-guided biopsy is the standard for the diagnosis of most breast lesions. However, there are still indications when excisional surgical biopsy should be recommended. The acquaintance of such indications is essential to adopt the multidisciplinary approach and provide the best patient care.

Adequate radiology/histology/clinical correlation is essential, in addition to the cautious post-biopsy surveillance for immediate detection of false-negative results, to prevent delays in cancer diagnosis. Clinical situations where open excisional biopsy should be recommended include [57]:

- Discordance between imaging findings and histopathology.
- Suspicious interval changes in a lesion previously diagnosed as benign pathology.
- High-Risk Lesions: Atypical Ductal Hyperplasia; Lobular carcinoma in Situ; Atypical Lobular Hyperplasia.
- Flat epithelial atypia, radial scar, or radial sclerosing lesion.
- Papillary lesions with atypia. Columnar alteration with cytologic atypia.
- Lesions not amenable to percutaneous biopsies include lesions close to the chest wall or immediately adjacent to the implant, inadequate breast tissue, patient intolerance to lie flat, and lesions superficially located within the skin.
- Lack of adequate retrieval of calcifications (as judged by the radiologist) when calcifications are targeted.

## 8. Preoperative evaluation of the breast in diagnosed breast cancer

The tumor size obtained by imaging is an important factor in the preoperative planning of breast cancer, whether it is the type of surgery or whether it initiates with neoadjuvant chemotherapy (NAC). Thus, mammography has been considered the standard imaging tool for detecting and assessing tumor size. Currently, the high-resolution US and MRI have been included in the diagnostic flowchart to achieve higher sensitivity [56], underscoring the surgeons' need to know the accuracy of each test to attain affordable breast cancer patient care.

Several studies [57–68] assess mammography, US, and MRI accuracy for measuring preoperative tumor size in patients who do not receive neoadjuvant chemotherapy. These studies showed correlations between ultrasonographic tumor size and pathologic tumor size ranging from 0.40 to 0.93, suggesting that breast ultrasound accurately predicts tumor size for those patients.

Although many studies have evaluated the value of preoperative magnetic resonance imaging (MRI) in invasive breast cancer, its role in clinical practice is still controversial, failing to show surgical outcome benefits [69–71]. A meta-analysis by Houssami and colleagues [69], which included 3,112 patients with breast cancer, found a significant increase in mastectomy rates in the MRI group (16.4% and 25.5%, respectively) with the non-MRI group (8.1% and 18.2%, respectively). This meta-analysis failed to show a surgical outcome benefit because there was no difference in re-excision rate following an initial breast-conservation, with 11.6% in the MRI group compared with 11.4% non-MRI group (P = .87). The authors suggest that a routine MRI in breast cancer patients could do more harm than good by identifying foci of disease beyond the lumpectomy bed that would have been eradicated by adjuvant radiation. Two prospective randomized trials [70, 71] assessed the effect of MRI on surgical outcomes in patients with breast cancer, with a primary end-point of reoperation rates (re-excision and conversion to mastectomy). The United Kingdom (UK) randomized trial (COMICE) [70] evaluated the

role of breast MRI in 1,625 women who had recently been diagnosed with primary breast malignancy. The trial showed no significant difference in the reoperation rate between the MRI group (18.7%) and the non-MRI group (19.3%). A twenty-eight percent increase in mastectomy rates was considered pathologically avoidable in the MRI group. The MONET trial [71] randomized 418 women with a nonpalpable suspicious mammographic or sonographic finding (BIRADS 3 to BIRADS 5 lesion) to receive preoperative MR Imaging versus usual care (mammography and ultrasound followed by biopsy). One hundred sixty-three women were diagnosed with breast cancer. There was a paradoxical increase in the re-excision rate in the MRI group (34%) and no difference in conversion to mastectomy (11%) compared with the re-excision rate in the non-MRI group (12%, P = .008) and conversion to mastectomy (14% *P* = .49).

## 9. Preoperative evaluation of axilla in diagnosed breast cancer

Ultrasound is the primary imaging technique to evaluate morphological abnormalities in the lymph nodes. It is a moderately sensitive method (between 26 and 80%) and can be very specific (ranges from 88 to 98%) [72, 73] when a morphological sign that indicates alterations is used as a diagnostic criterion such as general shape, the aspect of the cortex, the hilum and vascularization, rather than size [72–74]. A normal axillary lymph node sizes less than 10 mm, has a smooth and well-defined contour with an echogenic hilum (constitutes the majority of the node), and is surrounded by a thin and uniform hypoechoic cortex measuring less than 3 mm [75]. The ultrasound aspects of tumor infiltration in a crescent order of specificity are diffuse cortical thickening (> 3 mm); focal cortical bulge; eccentric cortical thickening; rounded hypoechoic node; partial or complete effacement of the fatty hilum; non-hilar blood flow on color Doppler; partial or total replacement of the node with an ill-defined (or irregular mass) and microcalcifications in the node [76]. The last step of the tumoral infiltration is spread to the perinodal fat [74, 76–78].

Axillary Ultrasound (AUS) and needle biopsy of abnormal-appearing nodes can appropriately allocate a positive predictive value for detecting nodal metastases [79, 80]. The use of ultrasound and biopsy in an abnormal lymph node improves sensitivity (88% vs. 61%), specificity (100% versus 85%), positive predictive value (91% versus 73%), and negative predictive value (100% versus 77%) compared to US alone [73–75]. The approach for identifying axillary metastases in women with T1 or T2 invasive breast cancer ranges from axillary imaging only in patients with suspicious findings (from physical examination of the axilla) [74] to axillary imaging being performed in all patients [5–7]. The identification of axillary disease on preoperative ultrasound was considered a reliable indicator for preoperative identification of axillary metastases, allowing the surgeon to proceed directly to axillary lymph node dissection (ALND) and omission of sentinel lymph nodes biopsy (SNB) [81].

However, the clinical utility of preoperative axillary imaging evaluation in women with T1 or T2 invasive breast cancer has changed with the American College of Surgeons Oncology Group (ACOSOG) Z0011 study [82] and International Breast Cancer Study Group (IBCSG)23–01 [83]. These randomized controlled trials have established that women with clinical T1–2 invasive breast carcinoma and clinically negative axilla with 1–2 positive sentinel lymph nodes (SLNs) can safely spare ALND without impacting overall survival, disease-free survival, or locoregional recurrence. Hence, several studies have attempted to evaluate whether it can manage patients without palpable adenopathy but with positive axillary nodes identified by ultrasound according to Z0011 criteria [84–87]. These studies have reported that between 43% and 51.9% of patients with nodal metastases on imaging had

pN1 disease at surgery, suggesting that a cohort of patients with axillary metastases detected by imaging alone can be candidates for the omission of ALND based on minimal nodal disease. Although a considerable percentage of patients with image-detected positive nodes have pN1 disease, multiple abnormal lymph nodes on axillary imaging were associated with a high likelihood of having pN2–3 disease and worse survival [88–90]. Axillary ultrasound seems to be more suited to exclude high axillary burden than quantifying the nodal disease volume in the event of abnormal axillary lymph nodes detected on preoperative axillary imaging.

In patients with clinically abnormal lymph nodes on physical exam, further evaluation of axilla with AUS with/without needle biopsy should consider appropriating to neoadjuvant chemotherapy, given the high nodal pathologic completed response (PCR) rates of 21 to 65% [91, 92]. Studies support the use of SNB for surgical staging of the axilla with false-negative rates of 8.4 to 14.2% [93–95]. Consequently, the de-escalation of axillary surgery for patients with metastatic axilla may not eliminate the need for the axillary US, but it certainly may make its use more selective.

## 10. Evaluation of the breast after surgical therapy

Breast imaging is a challenge in evaluating postoperative changes in breast cancer breast due to the wide range of imaging changes after surgery and the risk of recurrent disease. Ultrasound findings depending on the type of surgery performed: mastectomy, breast-conserving therapy, and breast reconstruction; whether radiation therapy has been performed; and the period elapsed from the end of treatment. Breast Ultrasound should perform in addition to, not as a replacement for, mammography [96, 97], for women who have undergone breast-conserving surgery and for the surgical site in patients with mastectomy. There are no post-mastectomy imaging guidelines since they are followed clinically with serial physical examinations. In the absence of breast reconstruction, the chest wall, subcutaneous fat, and skin can be evaluated with ultrasonography [98]. Cutaneous recurrence in patients after mastectomy may be palpable superficial mass.

Understanding the postsurgical imaging findings and their correlation is essential to ensure an accurate interpretation and recommendation. The most common changes in US imaging after breast-conserving surgery are:

- Skin thickening (more than 2 mm) and parenchymal edema, characterized by increased echogenicity and reticular enlargement of breast parenchyma (represented by dilated lymphatics or interstitial fluid). Those findings should start reducing six months after completing radiation therapy and returning to normal by two years of surgical treatment [99].

- Postsurgical scar or fibrotic dermal tissue after skin incision. Postsurgical scar appears as a discrete area of architectural distortion or hypoechoic interruption of the normal parenchyma with an irregular shape, not parallel orientation, strong acoustic shadowing, and absent vascularity. Fibrosis increases up to 18 months and then stabilizes. Therefore, after that period, the tissue that enhances the distortion must be considered suspicious, and biopsy should be considered.

- Postoperative fluid collections in the surgical bed have variable echogenicity (hypoechoic, hyperechoic, or anechoic). The anechoic lesions have a thin wall,

sometimes with debris or septa. Hematomas may be ill-defined or present as a mass with distal acoustic enhancement or shadowing and internal complex echoes [10]. Postoperative fluid collection decreases by six months, though, in a few patients, these may persist for years [100].

- Fat necrosis appears as hypoechoic or heterogeneous irregular mass, with acoustic shadowing. These findings may be misinterpreted as suspicious for malignancy. Therefore, in this case, correlating mammographic findings and tissue sampling is indicated (**Figure 6**).

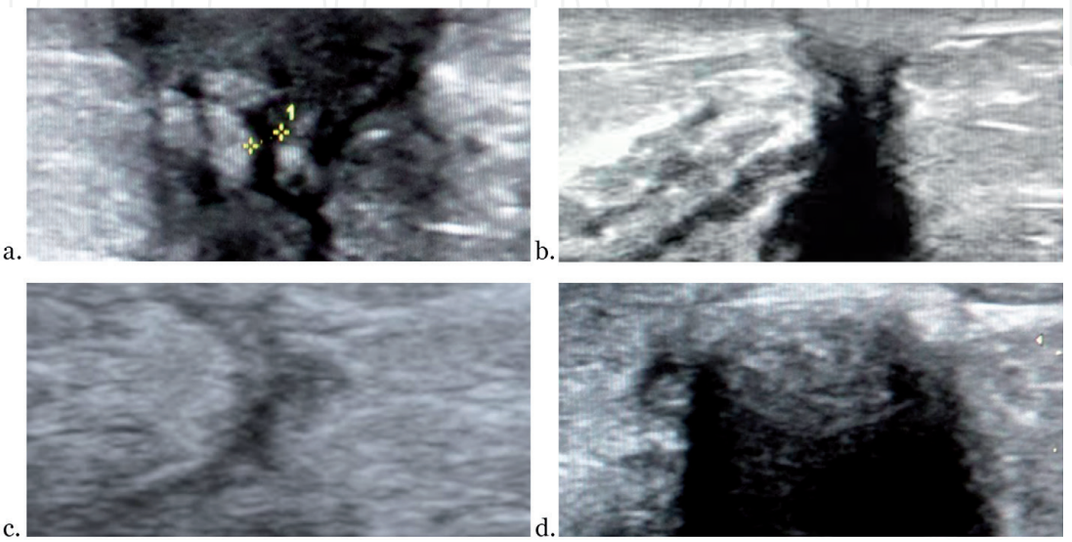


**Figure 6.**
*US Postoperative changes in Breast Conservation Treatment. (a) Parenchymal Edema, represented by reticular enlargement of breast parenchyma with dilated lymphatics (calipers) and interstitial fluid; (b) Postsurgical Scar, a discrete area of hypoechoic distortion with strong acoustic shadowing; (c) Postoperative Fluid Collection in surgical bed; (d) Fat Necrosis: Heterogeneous mass with acoustic shadowing.*

## 11. Evaluation and assessment of the breast after medical therapy

Radiological and clinical evaluation of residual tumor size after neoadjuvant chemotherapy (NAC) is vital for decision-making in breast surgical planning. Physical examination, mammography, and ultrasound are not accurate in assessing the tumor response to NAC. Chagpar et al. [101] examined the accuracy of clinical methods of tumor size assessment (physical examination, mammography, and ultrasound) in evaluating the tumor response to chemotherapy. The correlation coefficients for residual tumor size were estimated for physical examination of 0.42, ultrasound 0.42, and mammography 0.41. Interestingly, clinical measurement estimated by each of these modalities in only 66–75% of cases was within one centimeter of the pathologic tumor size. Likewise, Peintinger et al. [102] showed higher accuracy (89%) with the combination of mammography and sonography in predicting pathological residual tumor size after neoadjuvant chemotherapy, but a moderate agreement (69% of patients) in predicting pathologic tumor size within 0.5 cm.

Therefore, breast ultrasound for clinical evaluation of tumor size is moderately useful for patients receiving chemotherapy first [7]. However, breast MRI has shown an equal or better correlation for these patients and offers the best performance in assessing patients' response and predicting pathological tumor size non-invasively [103, 104].

## 12. Intraoperative ultrasound (IOUS) in breast surgery

Intraoperative US (IOUS) is a non-invasive procedure that enables the surgeon to perform intraoperative localization and guided excision of a nonpalpable breast lesion, as well as ultrasound-guided operation of traditional palpation-guided surgery [105–109].

Widespread preoperative malignant lesion localization strategies for surgery are wire-guided localization (WGL) and radio occult lesion localization (ROLL)-guided surgery to ensure the whole removal of imaging findings and allow margin clearance [110–112]. Rahusen et al. [110] reported that IOUS (89%) is superior to wire-guided surgery (55%) concerning tumor-free resection margins. A retrospective multicenter study [113] demonstrated that IOUS for nonpalpable invasive breast cancer was more accurate in obtaining adequate margins with the lowest rate of positive margins in the IOUS group (3.7%) than in the wire-localization group (21.3%) and radioguided occult lesion group (25%). Snider et al. showed a reasonable rate of tumor-free resection margins using IOUS (82%) with a smaller excision volume of healthy breast tissue than wire-guided surgery [114].

A meta-analysis [111] of patients with nonpalpable breast cancer treated with IOUS vs. wire-guided localization (WGL) showed that the rate of involved surgical margins for IOUS varies 0–19%. There was a statistically significant difference between IOUS and WGL regarding tumor-free margins favoring IOUS (OR = 0.52; 95%CI: 0.38–0.71). In the meta-analysis of Pan et al. [112], IOUS is an accurate method for localizing nonpalpable and palpable breast cancers by obtaining a high proportion of negative margins and adequate resection volumes in patients undergoing breast-conserving surgery. Thirteen studies were included. Eight were eligible for the impact of IOUS on the margin status of nonpalpable breast cancers; four were suitable for palpable breast cancers, and one was for both nonpalpable and palpable breast cancers. This meta-analysis showed a statistically significant increase in the rate of negative margins using IOUS for both nonpalpable and palpable breast cancers. IOUS-guidance enabled a significantly higher negative margin rate for non-palpable breast cancers than WGL-guidance (RR =1.26, 95% CI =1.09–1.46 from 6 prospective studies; OR = 1.45, 95% CI =0.86–2.43 from 2 retrospective studies). For palpable breast cancers, the relative risk (RR) for IOUS associated negative margins was 2.36 (95% CI =1.26–4.43) in 2 prospective studies, and OR was 2.71 (95% CI = 1.25–5.87) in 2 retrospective studies.

Breast surgeon-performed IOUS-guided excision does not depend on the radiology or nuclear medicine department. This procedure avoids the need for an additional localization procedure preoperatively, is non-stressful for the patients, and allows accurate intraoperative targeting and immediate confirmation of lesion removal with tumor-free margins. The use of this technique allocates hospital resources efficiently in resource-constraint contexts.

IOUS has demonstrated benefits in patients with palpable early-stage primary invasive breast cancer to completely excise the tumor with negative margins and small excision volumes, improving the result. COBALT-trial [107] was a multicenter randomized controlled trial for palpable cancer, comparing IOUS with palpation-guided surgery (PGS). Results of this trial showed a difference in tumor-involved margin of 3% of tumor-involved margins for the invasive component in the IOUS-group compared to 17% in the PGS-group, and thus a significant decrease in additional treatment required in the IOUS group (2% re-excision and 9% boost in IOUS vs. 7% mastectomy, 4% re-excision and 16% boost in the PGS group). Furthermore, secondary results of this trial showed IOUS had smaller odds of having worse cosmetic outcomes than PGS (OR = 0.51, P = 0.045).

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## Conflict of interest

The authors declare no conflict of interest.



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