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Problem-solving ultrasound

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For many years, technical factors may have prevented a broadening of the accepted indications for breast ultrasound (US) and limited some of the potential uses of US for problem solving from being realized. US analysis of masses was allowed only for cyst versus solid characterization and not for differentiation of benign from malignant solid masses [1]. More recently, transducer developments, systems improvements, and user experience have advanced US depiction of masses sufficiently to attempt classifying solid masses into categories defined by likelihood of malignancy [2,3]. What has changed in the last two decades is that whereas x-ray mammography has remained the only validated imaging technique for breast cancer screening, the contributions of other imaging methods to completing the problem-solving process have been recognized. Among the other imaging methods, US is second to mammography in most cases because of long experience with its use, accessibility and relatively low cost of the equipment, and the opportunity it affords for real-time guidance of aspiration or needle biopsy.

Just as systematization of descriptors for mammography has provided a framework for assessment, management, and reporting, a lexicon of US descriptors makes possible the consistent classification of breast lesions [2,4–6]. Lesion analysis, using a combination of features to analyze a mass, has enabled breast imagers to become more specific in their categorizations of solid masses. Categories similar to those used for mammographic final assessments are being applied to US and multimodality breast imaging assessments [3,4]. Although the equivalent US criteria for category 3 (probably benign) mammographic lesions remain to be validated by data from multiple sites, the presumed fibroadenoma, a macrolobulated, circumscribed, hypoechoic mass with orientation parallel to the skin (Fig. 1) has become the prototype of the probably benign mass through common use [2–8].

The indications listed in the American College of Radiology Practice Guideline for the Performance of the Breast Ultrasound Examination summarize the ways that US is currently used to solve diagnostic problems and include the following [9]:

1. Identification and characterization of palpable and nonpalpable abnormalities and the further evaluation of clinical and mammographic findings
2. Guidance of interventional procedures (discussed elsewhere in this issue)
3. Evaluating problems associated with breast implants
4. Treatment planning for radiation therapy
5. Initial imaging technique for young (under 30), lactating, and pregnant women

Palpable and nonpalpable abnormalities

When a patient complains of a mass or thickening of the breast or is referred for evaluation of a pal-

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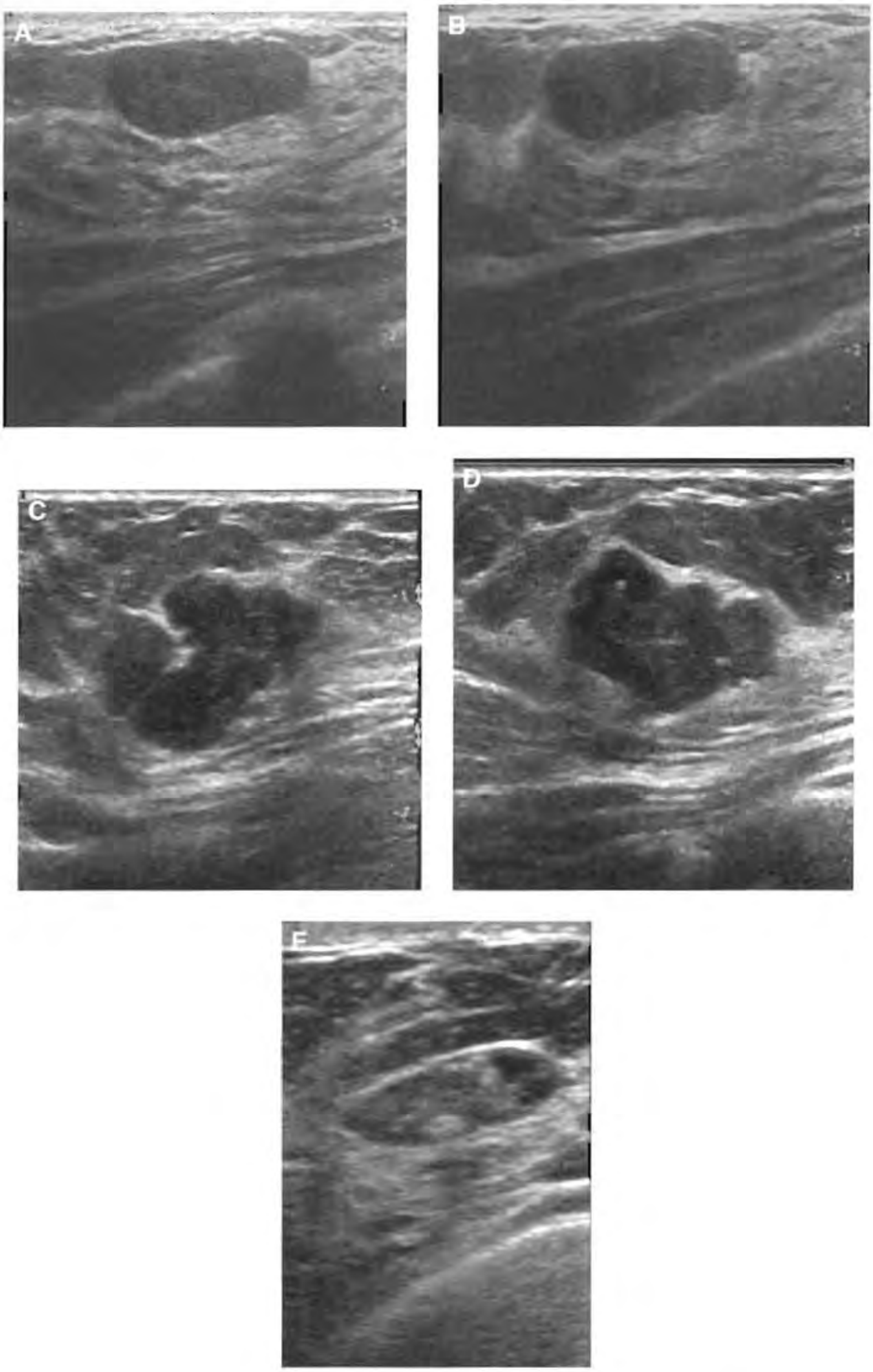

Fig. 1. Fibroadenomas. (*A,B*) Typical fibroadenoma. Two US views show oval, macrolobulated, circumscribed, hypoechoic mass oriented parallel to skin. (*C,D*) Orthogonal US views show a conglomeration of fibroadenomas, presenting as a microlobulated, irregularly shaped mass requiring tissue sampling. (*E*) A small fibroadenoma containing coarse calcifications and tiny cysts.

pable finding on clinical examination, in general, mammography is the initial examination if the patient is over 30 to 35 years. The usefulness of US in problem solving depends in part on the overall mammographic breast density [10]. In women with heterogeneously or extremely dense breasts, a mass that might explain the physical finding can be imperceptible on a mammogram.

In the dense breast, US is indicated for a palpable mass or one suspected in, or partially obscured by, fibroglandular tissue. The mammographic evaluation may include a view tangential to the mass or thickening, on which a small, radiopaque skin marker should be placed. This view may allow the convex anterior border of a mass to be silhouetted in the subcutaneous fat. A well-exposed mammogram in dense breast tissue can depict calcifications in or near the mass, but an endless number of additional views that contribute only to the radiation dose without profiling the mass should be avoided. US has the triple function of lesion identification, characterization, and guidance for biopsy, if indicated.

Additionally, if US is directed to an area of calcifications, an associated mass may be seen (Fig. 2). The mass may increase the likelihood of invasive disease, although rarely ductal carcinoma in situ can present as a mass [11], and US can be used as the imaging guide for tissue sampling (with radiography of the cores to confirm calcifications within the specimens). This application of US is becoming more common in practice.

Where the pathologic process itself contributes to overall breast density significantly enough to limit mammography, US is indicated. An example is an inflammatory process, such as mastitis. Here, US can be used to identify and guide drainage of an underlying abscess. When inflammatory carcinoma is suspected, tumor masses that are hidden in dense, edematous breast tissue may be found with ultrasound or MR imaging (Fig. 3) [12].

Less clear is the need for US in a site of clinical concern when the mammogram in two views shows the area to be fatty. Although US may not be indicated in these cases and the standard of care does not require it, in the author's experience US has helped at times to provide specific answers when mammography has been negative, the tissue fatty, and a mass distinctly palpable (Fig. 4).

In the evaluation of a palpable mass, a recent study of 420 patients with 455 palpable masses found that when mammography is negative, and targeted US is also negative, the negative predictive value for cancer is high (99.8%) [13]. A 99.9% negative predictive value of a negative clinical examination, mammography, and US was also reported for 3516 patients studied by investigators from The Netherlands [14]. If US is performed to confirm or to characterize a mass suspected on mammograms, and if no mass is found, the parenchymal focus that might explain the mammographic findings can be correlated with the shape, size, and anatomic arrangement of fat and fibroglandular tissue on US (Fig. 5). This correlation may support US exclusion of an abnormality, but to direct patient management, the reliability of these observations still remains to be established.

Evaluating problems with breast implants

Indications for breast US in women with augmented breasts are the same as those for women without breast prostheses with the additional application of US to determine the nature of palpable masses as either originating in the breast or related to the implant as a wrinkle, fold, or shell irregularity or a silicone granuloma. Although MR imaging has been found to be more sensitive and specific in identifying intracapsular and extracapsular rupture, the US "snowstorm" or "echogenic noise" appearance of extravasated silicone is characteristic (Fig. 6) [15,16]. US can also suggest intracapsular rupture, whatever its clinical significance, by depicting shreds of implant shell floating within the silicone gel producing a stepladder of echogenic lines or wavy echogenic bands [17]. For evaluating a palpable mass, before recommending MR imaging, US should be used as a lower-cost, more rapid method of making the important distinction of the origin of a mass as within the breast rather than related to the implant. At the same time, if the mass is of breast origin, it can be characterized as cystic or solid, and its features analyzed further to assign a level of suspicion of malignancy.

Treatment planning for radiation therapy

After the surgical excision of a malignancy, a seroma nearly always develops. Septa or clumps of echogenic material may be present within it, but unless the patient shows signs of abscess, the fluid collection should not be aspirated (Fig. 7). Drainage is thought to compromise the cosmetic result by leaving a crater in the breast, and drainage of the fluid collection is unnecessary. After 6 to 12 months have elapsed, the seroma is resorbed gradually and replaced by scarring with imaging features similar to

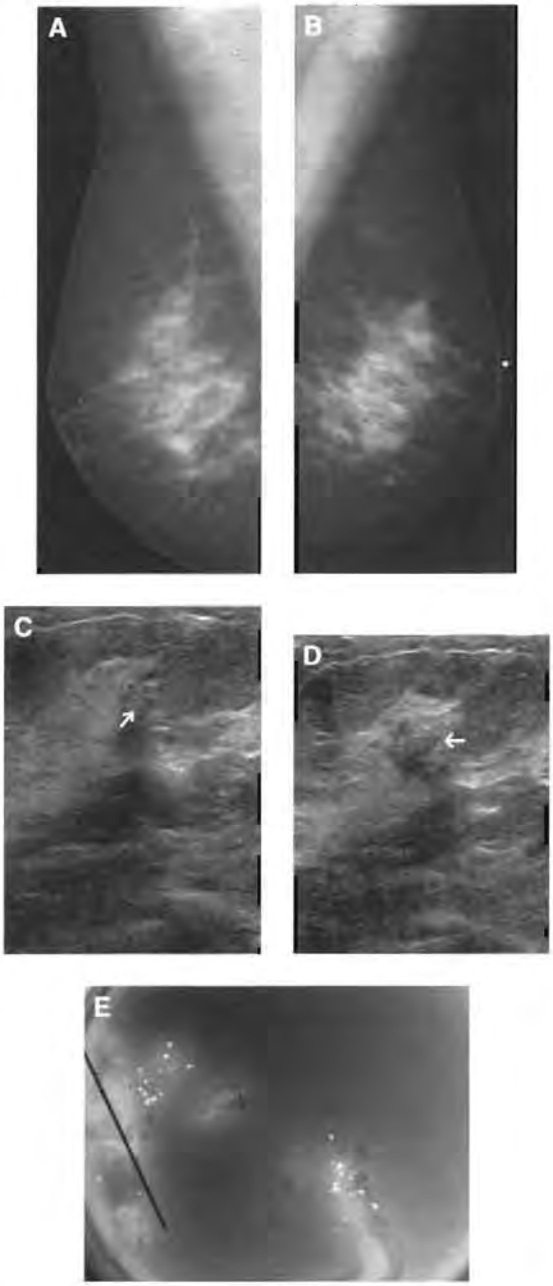

Fig. 2. Infiltrating and intraductal carcinoma. (*A,B*) Mediolateral oblique mammograms with heterogeneously dense parenchyma. Palpable mass in left breast is marked by BB. (*C,D*) Orthogonal US views show microcalcifications within the echogenic fibroglandular parenchyma (*arrows*) and within an irregularly shaped, hypoechoic mass. (*E*) Specimen radiograph of cores obtained with US guidance shows numerous calcifications within the cores.

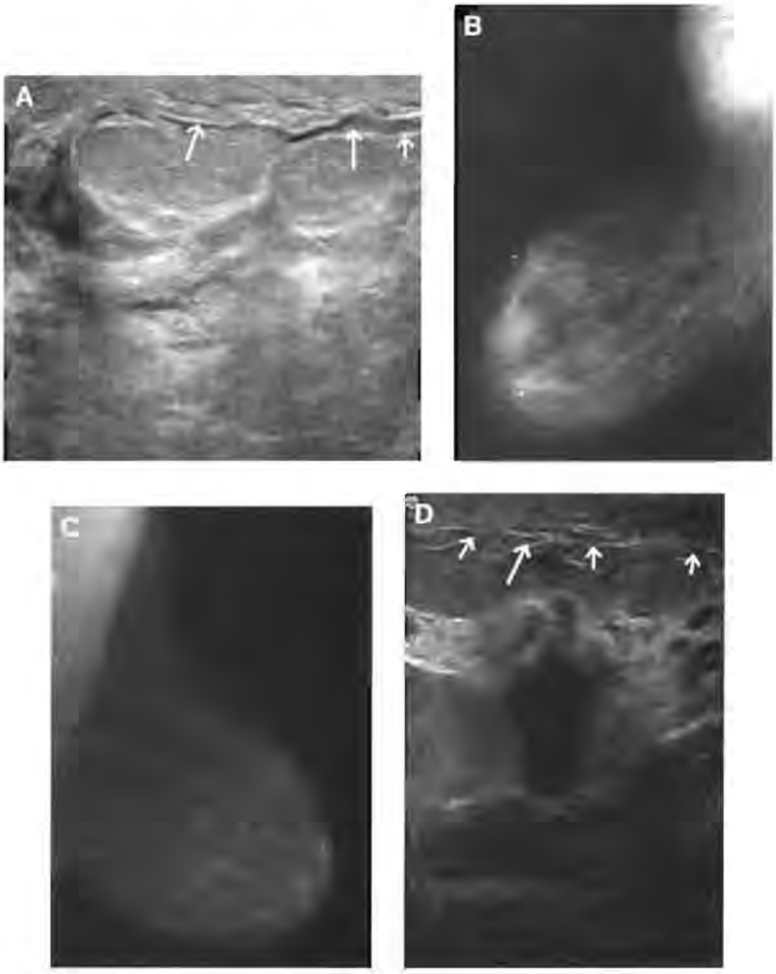

Fig. 3. Inflammatory carcinoma. (*A*) Sonogram shows skin thickening (*short arrows*) and edema (*long arrows*), the hallmarks of inflammatory carcinoma. (*B, C*) Mediolateral oblique mammograms of another patient show increased density, edema, and skin thickening of the right breast compared with the left. (*D*) US image is brightly echogenic, characteristic of edematous tissue, with thickened skin (*short arrows*) and network of hypoechoic lines representing interstitial fluid or lymphatics (*long arrows*). Note a small, irregularly shaped hypoechoic mass (*), invasive ductal carcinoma, not well seen on the mammogram.

those of malignancy [18]. The margins of the scar are spiculated and indistinct, and posterior acoustic shadowing replaces the seroma's enhancement. Knowledge of the marginal status at excision, and the ability to follow the path of the scalpel from the skin, where there is a "V," down to the tumor bed helps in excluding recurrence (Fig. 8) [18]. As with mammography, a new mass or other interval change at or near the lumpectomy site can signal a recurrence.

There are various methods of demarcating a lumpectomy site for radiation therapy. CT can be used, and some surgeons mark the boundaries of the lumpectomy site with surgical clips to facilitate radiation treatment planning [19,20]. Just as US can provide the shortest distance from the skin to a carcinoma for presurgical needle-wire localization of a nonpalpable mass, however, once the excision has been performed, the target area for radiation therapy can be mapped with US more directly using its real-time capabilities [21]. For whole breast radiation with a boost, the depth of the tumor bed from the skin surface can be shown, the dimensions and shape of the fluid collection depicted on orthogonal views, and its volume calculated from dimensions in these views.

More recently, partial breast irradiation, a brachytherapy procedure with radioactive seeds delivered to the lumpectomy site through a balloon catheter (MammoSite, Proxima Therapeutics, Alpharetta,

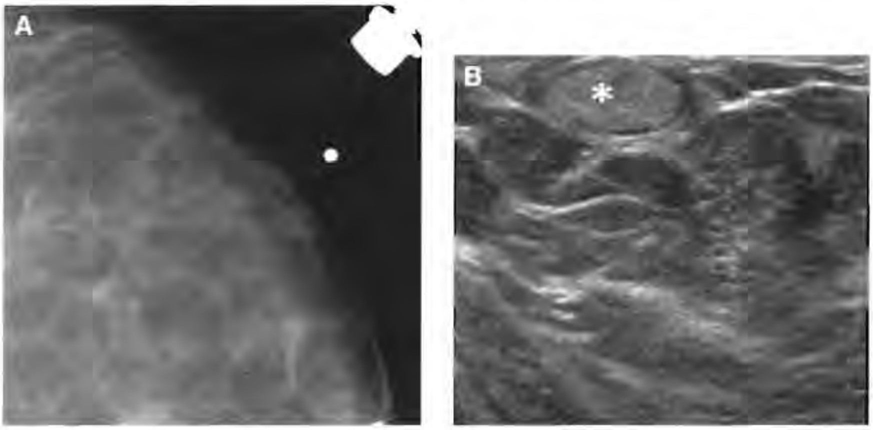

Fig. 4. Lipoma. Mass felt on clinical and self-examination. (*A*) No mass is seen on a spot compression tangential mammographic view. A small metallic pellet marks the site of the mass. Although no abnormality can be identified on the mammogram, the sonogram (*B*) shows a small lipoma (*) surrounded by fat lobules, providing a specific answer to the clinical question.

Georgia), has become an option for older women with small invasive tumors. High-dose radiotherapy is delivered twice a day through these catheters, which can be placed either at surgery or percutaneously with US guidance (Fig. 9). If the device is to be placed with US guidance within the first weeks following surgical excision of the tumor, US is used to determine eligibility. The seroma should be round, if possible, and at least 3 cm in diameter. The key measurement is the distance from the skin to the top of the seroma, which should be at least 0.7 cm to ensure even and equal radiation throughout the field.

Young, pregnant, and lactating patients

In stipulating that US be the initial imaging technique for women 30 years of age and younger [9], it should be noted that most of these patients have not yet reached the age recommended for mammographic screening and have come to clinical attention

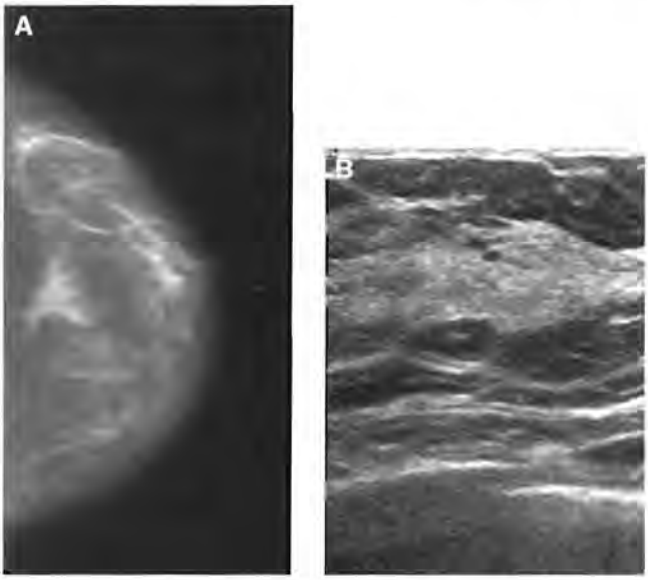

Fig. 5. Correlating mammography and US. (*A*) Craniocaudal mammographic view shows triangular focal asymmetry in central posterior breast. (*B*) Sonogram shows triangular fibroglandular area with fat anteriorly and posteriorly. Allowing for upright mammographic position and supine position for US, the size, location, and tissue pattern correspond.

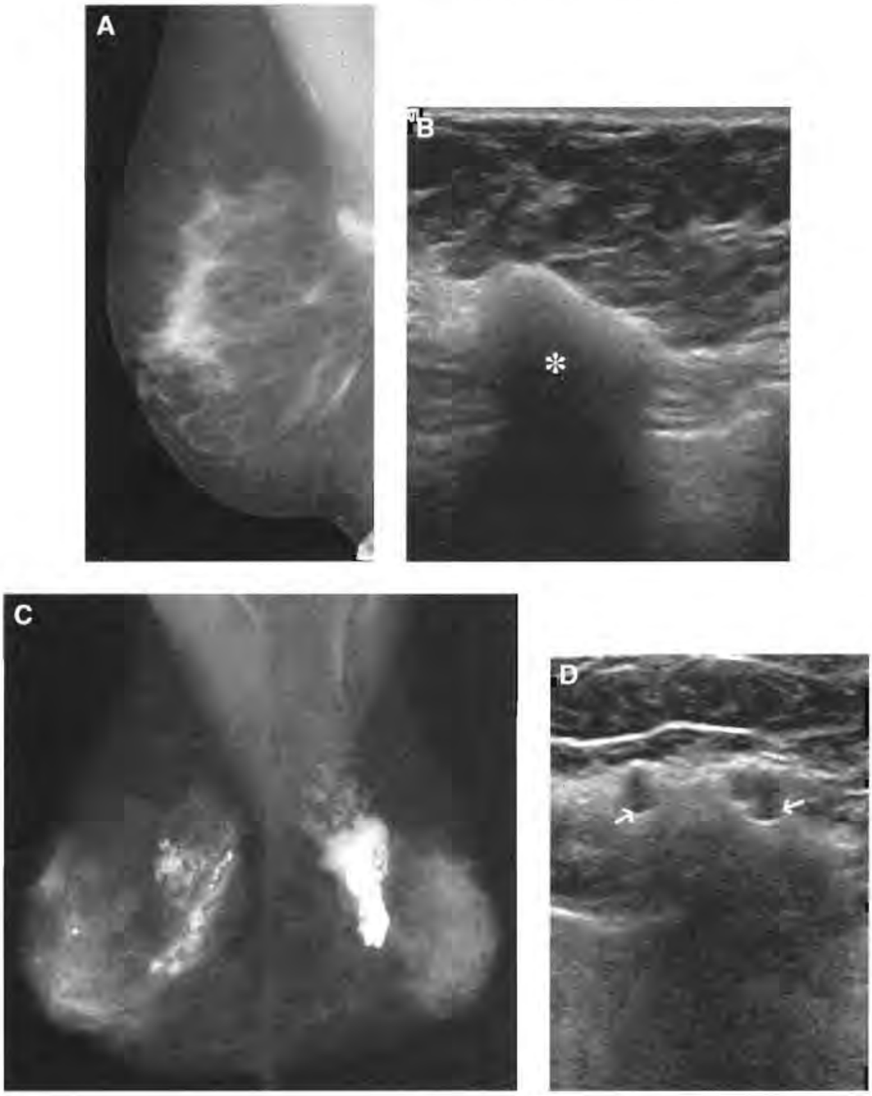

Fig. 6. Silicone. (*A*) Mediolateral oblique view of right breast shows anterior portion of dense lymph node in axilla of patient whose silicone implant had been removed 2 years earlier. (*B*) Sonogram of lymph node displays signature characteristic of silicone in tissue: "snowstorm" pattern of echogenic noise (*asterisk*) that fades posteriorly. (*C*) Digital mediolateral oblique mammograms show capsules containing residual silicone. Silicone implants had been removed 2 years earlier. (*D*) The same pattern of echogenic noise seen in (*B*) is present in a sonogram of the retained silicone and capsule. The angular hypoechoic nodules (*arrows*) represent silicone granulomas.

because of palpable masses, pain, or signs of mastitis and abscess. If the US findings suggest malignancy, bilateral mammography is indicated for assessing extent of disease before any intervention [22,23]. For example, mammography might reveal microcalcifications not seen or suspected at US or an area of architectural distortion not appreciated sonographically.

Fear of radiation exposure is unjustified; radiation exposure to a fetus or to the nongravid pelvic organs from mammography, a highly collimated examination, is near zero [21]. Where mammography might show significant pathology not seen at US, the benefits of mammography outweigh the perceived negatives of an x-ray study.

Fig. 7. Postsurgical fluid collection. After lumpectomy for carcinoma, fluid accumulates in the tumor bed. Although the fluid may contain clumps of echogenic material and septa, unless there are clinical signs of abscess, aspiration of the collection is unnecessary. The fluid is resorbed over a period of many months, to be replaced by scarring.

Fig. 9. Partial breast irradiation. A balloon catheter placed percutaneously with US guidance is seen within the lumpectomy site. The saline-inflated balloon is the vehicle for delivering radiation evenly to the tumor bed and surrounding region. Radiation therapy is given twice a day and completed in 5 days.

When US of a palpable mass in a young patient shows a solid lesion with typical benign features, such as oval shape, circumscribed margins, and orientation parallel to the skin, mammography may be unnecessary [22]. Management of the mass may include clinical or US follow-up; tissue sampling if the patient or physician requests it; or excision for abatement of symptoms, such as pain. In general, there is no consensus concerning the need for mammography in a patient less than 30 years of age when an initial US examination is negative.

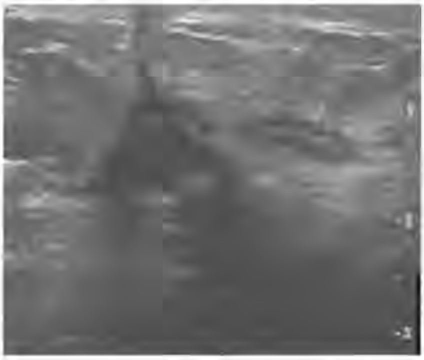

Fig. 8. Tract to the tumor bed. The skin at the incision site is thick. Beneath a V-shaped hypoechoic area in the skin is the linear path of the scalpel leading to the tumor bed. Identification of this tract is helpful when scarring is difficult to distinguish from tumor recurrence.

Controversial or evolving applications of breast ultrasound in problem solving

Characterizing multiple masses

A *Rule of Multiplicity* is often invoked in evaluating and managing multiple masses [24]. This dictum states that multiple masses with similar, mammographically benign features need not be characterized with US; the recommendation is for annual mammographic follow-up [24]. Others believe that the capability for increasing interpretive accuracy is promoted with a supplemental US examination. Additionally and anecdotally, many breast imagers will relate, and some have reported their experiences in finding an unsuspected cancer adjacent to cysts or benign solid masses as they scan to characterize masses observed on mammograms [25–28]. US is time consuming, and its acknowledged operator dependence arouses skepticism in using US to follow-up masses after their initial characterization [29,30]. The use of US in continued patient follow-up of multiple masses is variable, although improvement in interpretive consistency has been noted recently [30], and there is no established standard to guide patient management in these cases.

If the breasts are fatty, soft tissue density masses are more conspicuous against the gray background of fat. Once a mass has been diagnosed with US as a simple cyst, it is not difficult to follow its increase or decrease mammographically. If breast tissue is heterogeneously or extremely dense, confident mammographic follow-up may be more difficult and, in this scenario, US may be used. There is no established standard, however, based on current data. Any new mass, either palpable or evident on the mammograms, should be studied with US [9,22].

For extent of disease bilaterally, including axillary evaluation, in breast cancer patients

When establishing a candidate's eligibility for breast conservation when the breast tissue is dense and the index carcinoma was seen best with US, there has been increasing use of US to survey the entire affected breast and the contralateral breast for additional foci [10,28]. To substantiate the effectiveness of this approach, however, additional data are awaited from a recently opened multicenter trial, Screening Breast Ultrasound in High Risk Women, American College of Radiology Imaging Network (ACRIN 6666).

The US assessment of extent of disease has also extended to the axilla of the affected breast. In scanning the axilla, if lymph nodes are seen to have cortical contour bulges or masses (Fig. 10), US-guided percutaneous needle biopsy can confirm metastatic involvement, obviating the need for a sentinel node procedure [31].

Fig. 10. Metastatic lymph node. In patient with upper outer quadrant infiltrating ductal carcinoma, axillary lymph node is not enlarged. A cortical bulge (*arrow*) containing an area of echogenic heterogeneity suggests the metastatic involvement confirmed by US-directed needle biopsy.

Establishment of multicentricity can alter treatment decisions, as is becoming recognized with increasing incorporation of MR imaging in the imaging evaluations of breast cancer patients. With identification of additional cancers in breast quadrants other than that in which the cancer was originally found, plans for conservation have been changed to mastectomy. Both US and MR imaging are being used, sometimes competitively, for assessing extent of disease in a woman with one established breast cancer focus. A recent study found that a combination of mammography and whole breast US was adequate in most cases and certainly less costly [32], although data are accumulating in support of the efficacy of MR imaging to assess extent of disease. Determining the best imaging methods for judging extent of cancer involvement is an area of active research.

Summary

Breast US makes important contributions to problem solving. The accepted indications for using US to examine the breasts are discussed here: evaluation of palpable and mammographic masses; evaluating implant problems; radiation treatment planning; and as the initial imaging technique in young (30 years of age and under), pregnant, and lactating patients. Newer or controversial applications are also discussed, including use of US to look for an associated mass in an area of microcalcifications seen on mammograms; initial evaluation and follow-up of patients with multiple similar, benign-appearing masses; and survey US for extent of disease and treatment planning for patients with at least one established focus of breast cancer.

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