Advanced Breast Ultrasound and Interventions: An Update

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Introduction

Ultrasound (US) technology has made progress in detecting and characterizing breast lesions, using frequencies between 7 and 18 MHz in combination with advanced tissue imaging technologies such as compound and harmonic imaging, volume scanning, modern color flow and elastography. The updated Breast Imaging Reporting and Data System (BI-RADS®) lexicon incorporates these new technological concepts and their impact on management. To date, description of a lesion should cover the new BI-RADS® US categories of vascularity and elasticity as associated findings. US constitutes the assessment method of choice for women with clinical signs and symptoms. Fundamental US enhances sensitivity for detecting cancer by 6-30% in symptomatic breast cancer patients. In risk patients with radiodense breasts, additive US to screening mammography improves the supplemental diagnostic detection rate after negative mammography by three to four per 1,000 women with dense breasts. The generally accepted role of US in population-based screening focuses on the assessment of suspicious mammographically detected lesions. US is indicated and routinely used in breast centers for preoperative staging, to monitor therapy and to keep patients under surveillance after breast conservation. US-guided core needle biopsy is the standard interventional technique for all breast lesions that correlate with findings of other imaging modalities. Sensitivity of US-guided large core needle biopsy (CNB) is 93-98%; specificity ranges from 95% to 100 %. The diagnostic accuracy of US-guided vacuum-assisted biopsy (VAB) is close to 100%. US-guided needle aspiration and CNB of the axilla should be used preoperatively to define metastatic lymph node involvement. Breast cancer screening based on automated whole breast US is an upcoming future horizon that will need sophisticated transfer of technological advancements to updated epidemiological concepts.

Basics of Ultrasound Anatomy

Breast anatomy is the basis for understanding breast US. The breast is a modified skin gland enveloped in fibrous fascia. The undersurface of the breast lies on the deep pectoralis fascia. The superficial pectoralis fascia is located beneath the skin and nipple. The breast is composed of three major structures: skin, subcutaneous tissue and breast tissue, which contains parenchyma and stroma. The parenchyma is divided in 15-20 lobes or segments that converge at the nipple in a radial arrangement. Each lobe contains 20-40 lobules. Each lobule contains 10-100 ductules or acini. The terminal-duct lobular unit (TDLU) is the functional unit composed of a lobule and its terminal duct. Major ducts join below the nipple in a net-like pattern and widen in a portion named the lactiferous sinus before opening into the orifices of the nipple. The converging larger ducts drain the segmental ducts arising from subsegmental ducts and terminal ducts. To date, the definition of the ducts and associated TDLUs within a segment using a ductal or radial scanning examination technique complements the transversal and sagittal examination [1, 2]. Several proliferative breast diseases including ductal carcinoma in situ (DCIS) arise from the TDLUs (Fig. 1). Only DCIS cells expand throughout all ducts (Fig. 2). However, distended TDLUs due to DCIS develop rarely, while high-resolution US (HRUS) detects distended TDLUs frequently in various benign lesions. Therefore, additional information is necessary, such as a suspicious segmental distribution or the correlation to suspect imaging findings with mammography or magnetic resonance imaging (MRI). Tiny changes, as small as 2-5 mm in diameter, can be dismissed in analogy with MRI-detected foci. In contrast, such small pseudocystic changes must be assessed in the presence of concern about multifocality or duct extension of DCIS.

The echogenicity of fat is the reference for comparing other anatomical structures within breast US [1, 2]:

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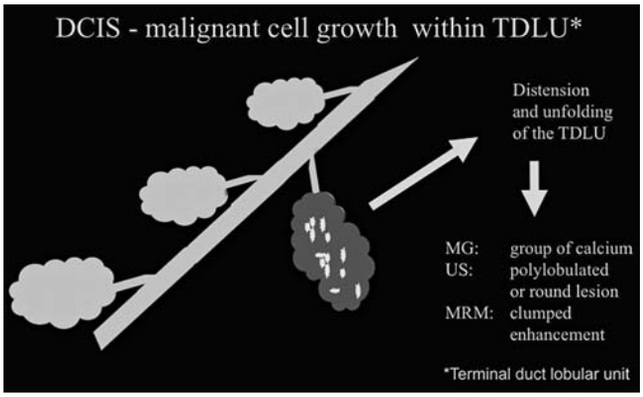

Fig. 1. Ductal carcinoma in situ (DCIS): malignant cell growth resulting in a distension of the terminal-duct lobular unit (TDLU). Various other benign proliferative or fibrocystic changes develop along a distinct genetic and morphological pathway and can also result in a distension of the TDLU. Associated calcifications within the TDLU develop in DCIS, fibrocystic changes, sclerosing adenosis, and other forms of adenosis. Expanded TDLUs can be depicted by mammography, ultrasound, or magnetic resonance mammography. Corresponding diagnostic criteria are listed in the text (for color reproduction see p 344)

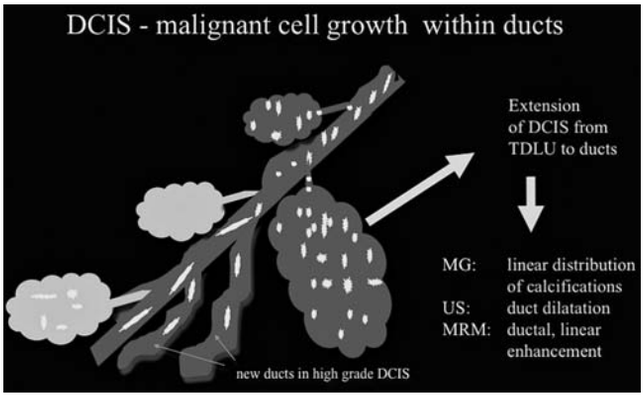

Fig. 2. Ductal carcinoma in situ (DCIS): malignant extension of DCIS into the ducts and other terminal-duct lobular units (TDLUs). New ducts can be formed in high-grade DCIS. Corresponding diagnostic criteria are given and focus on the linear extension or dilatation of ducts in all imaging modalities (for color reproduction see p 344)

- Isoechoic echogenicity is found in fat, epithelium, loose periductal and intralobular fibrous tissue and some TDLUs
- Hyperechoic echogenicity is found in skin, Cooper's ligaments, stromal fibrous tissue (interlobular) and some TDLUs
- Hypoechoic echogenicity is found in nipple and blood in vessels
- Anechoic echogenicity is found in dilated TDLUs (cysts), ducts and lymphatics

Physics and Equipment

US of the breast provides physical information about the impedance of tissue interfaces that influence US transmission and reflection across the breast. The different physical base of US, X-ray mammography and MRI of the breast explains the independent and complementary diagnostic information given by each modality. The most relevant advances made in recent years are due to high-frequency US transducer equipment using frequencies between 7 and 18 MHz. Scanning with 15 MHz in comparison with 7.5 MHz results in a lateral (0.4 mm) and axial (0.2 mm) spatial resolution that is twice as high as the spatial resolution at 7.5 MHz. On the other hand, penetration depth is reduced to half. Compounding and harmonic imaging improves contrast resolution and reduces speckle artefacts. The high spatial and contrast resolution of modern breast US equipment has expanded the detection and conspicuity of subtle lesions the size of expanded TDLUs such as DCIS and microinvasive lesions. Color Doppler techniques detect and characterize blood flow within lesions, and this allows discrimination between solid nodules and complicated cysts. Three-dimensional (3D) diagnostic imaging of the breast includes multidimensional reformations, reconstructions and tomographic US. The additional diagnostic information of 3D US focuses on demonstrating suspicious radial retractions around a tumor in the coronal plane, which is unique to this technique. Elastography reflects strain properties of lesions. Malignant nodules are generally less compressible than benign tissue. Strain, shear wave and semistatic elastography are the actual techniques to assess tissue stiffness. Elastography can downstage BI-RADS® 3 lesions independent of the applied technique. The future role of elastography continues to be evaluated. New horizons in high-end US technology encompass miniaturized and portable US systems, and automated whole breast US, and imaging fusion of US information with digital mammography, tomosynthesis, contrast enhanced dual energy mammography, MRI or positron emission tomography [3, 4].

Indications for Breast Ultrasound

A list of updated recommendations pertaining to indications is given in Box 1 (modified according to [3]). US is the first-line imaging technique for women <40 years presenting with symptoms or clinical signs. In the presence of a suspicious lesion, US is the method of choice to guide core biopsy in order to harvest tissue. US-guided VAB is used increasingly to diagnose intraductal lesions, small architectural distortions and borderline lesions; to complete preoperative staging in patients with extensive ductal component; and for therapeutic excision. Stereotactic-guided VAB is the method of choice to sample screen-detected microcalcifications and architectural distortions not seen on US. In the dense breast, the combination of US and screening mammography improves

Box 1. Updated indications for high-resolution US [AQ1]

Advanced indications for high-resolution US:
- Differentiation of cysts and solid tumors
- Differentiation between solid, benign and malignant lesions
- Characterization of palpable abnormalities
- Assessment of mammographic screening abnormalities
- Dense breasts showing with reduced mammographic sensitivity
- Diagnosis and follow-up of women with benign breast disease or risk lesions
- Women, during pregnancy or lactation
- Significant nipple discharge
- Under hormonal replacement therapy
- Inflamed breast and abscesses formation
- Extended screening for high-risk patients
- Second look after magnetic resonance mammography
- Guidance of interventional procedures, such as fine needle aspiration, core biopsy, diagnostic and therapeutic vacuum biopsy and preoperative tumor localization, axillary lymph node biopsy
- Preoperative staging of lesion size, skin and nipple distance for planning breast conservative surgery, mastectomy or oncoplastic reconstruction with implants, assessment of multifocality, multicentricity, intraductal extension, lymph node changes and contralateral lesions
- Preoperative staging and follow-up under neoadjuvant chemotherapy
- Surveillance after breast-conservation therapy
- Silicone implants

US ultrasound

cancer detection considerably compared with mammography alone, but with an increase in biopsy rate. The additional diagnostic yield of US after negative mammography is 3.2:1,000 women with dense breasts. Intraoperative surgeon-performed US focuses on accurately defining the resection segment or sector and the margin analysis of the resection specimen. MRI is useful preoperatively to assess the extent of ipsilateral disease and exclude contralateral breast cancer, particularly for women at increased risk of mammographically occult disease. Second-look US can detect up to 50% of magnetic-resonance-enhancing cancers with negative mammography [5-8].

Examination Technique

The International Breast Ultrasound School (IBUS) and American College of Radiology (ACR) guidelines for breast US examination advise a systematic, comprehensive and reproducible examination technique, followed by documentation, description, reporting, classification and recommendation. The examination starts with proper positioning of the patient in a supine or anterior oblique position depending on the breast volume, with elevation of the ipsilateral arm. Positioning should result in a maximum flattening of the breast portion being examined. Automated tissue optimization and focal zone and field of view settings should be optimized before scanning with the transducer perpendicular to skin. A minimum of two scan planes is recommended in whole breast US. Image analysis of a detected lesion or pseudolesion requires rotation of the transducer over the entire lesion using changing compression intensities and angulations. Radial imaging of adjacent ducts is mandatory to assess ductal extensions. BI-RADS® descriptors and further criteria of additional elastography, 3D tissue criteria, vascularization and associated lymph node morphology characterise a state-of-the-art lesions assessment by US. The o'clock position and distances to skin and nipple describe the exact localization of a lesion within the volume of the breast. Indication of palpability and imaging correlation to other modalities complete the documentation [9-12].

Concepts of Interpretation Based on Ultrasound BI-RADS® Descriptors

The categorization of a mass finding in all modalities relates to a 3D macropathological tissue lesion. The pathology defines lesion shape, margin and texture. These features have already been described individually for the varying modalities. A uniform wording of the major diagnostic criteria for all modalities would be logical. The BI-RADS® concept took a first step in this direction and was designed primarily as a mammographic language with a clear, defined terminology. In 2003, the ACR published the Breast Imaging Atlas, which is a BI-RADS® lexicon for mammography, US and MRI. The US chapters were originally arranged under the chair of Ellen B. Mendelson [11], and the descriptors or diagnostic criteria are presented with increasing probability of malignancy. Descriptors of a mass include shape, orientation, margin, boundary, echo pattern, posterior acoustic feature and characteristics of surrounding tissue, as well as associated distinguishing findings. The combination of several descriptors predicts malignancy better than one single descriptor. However, the reader should use further explanatory elements in the guidance chapters of the atlas, such as clinical context conditions, tumor biology and epidemiological prevalence, to cover the complex field of breast lesions. Assumptions regarding the expected prevalence and individual risk for cancer in a patient drive the intuitive recommendation for or against a biopsy and influence the choice of a final BI-RADS® assessment category. In other words, the threshold for performing a biopsy is lower for a probably benign-looking lesion compared with a screening setting if advanced age, large lesion, palpability or individual high-risk situation concern the reader. BI-RADS® categories 3-5 imply a defined probability of malignancy for each category. For BI-RADS® 3, these probabilities are <2%, for BI-RADS® 4 between 3% and 94%, and for BI-RADS® 5 ≥95%. Most European US societies have adopted or modified the ACR BI-RADS® US guidelines. In addition to the 2003 US descriptors, various features have been

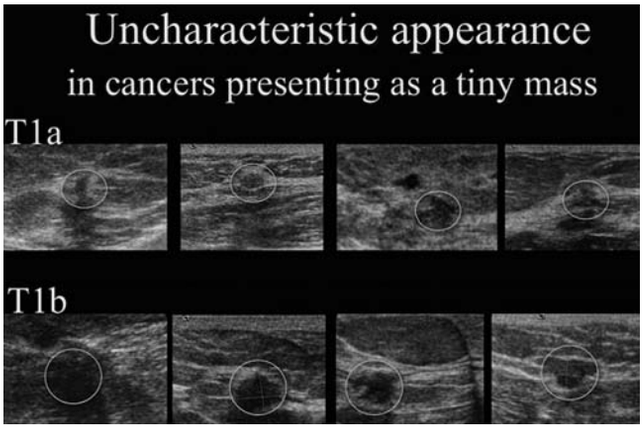

Fig. 3. Uncharacteristic appearance of small cancers stages T1a and T1b. All these cancers have been detected by screening mammogram and correlated to ultrasound secondarily during assessment (courtesy of Screening Centre Southwest Lower Saxony; Praxis Drewes and Partners). Several small benign lesions resemble the presentation of small cancers (for color reproduction see p 344)

Box 1. Underlying concepts of BI-RADS® US assessment categories

Underlying concepts of BI-RADS® US assessment categories:
- Categorization and management depends on the most suspicious diagnostic criterion
- Benign lesions must look typically benign; no suspicious image descriptor
- Malignant lesions frequently show one or more suspicious criteria
- Predefined thresholds for positive predictive value or cancer risk influence the classification in categories 2-5
- Overall BI-RADS® category must consider further clinical context conditions, expected prevalence and other risk factors in addition tomorphological criteria of each imaging modality assessment category
- Typical indicators of benignancy such as cysts, fat in a lesion (hamartoma) or benign macrocalcification (popcorn calcification with fibroadenoma) diagnosed by multimodality evaluation can downgrade overall assessment category compared with US category
- Indicators of potential malignancy in other modalities can upgrade overall assessment category compared with US category
- Overall assessment category should also be based on the most urgently needed procedure. This point of view ensures critical re-evaluation of final assessment category

BI-RADS® Breast Imaging and Reporting Data System, *US* ultrasound

suggested, such as elastic compressibility, movability, 3D criteria, detailed lymph node morphology and others. Further prospective multicenter studies are needed to validate the complementary diagnostic importance of such associated features as an adjunct to the basic characteristics of a lesion [12, 13]. Recently, several authors disclosed that interobserver agreement with the new BI-RADS® terminology is good, and validated the lexicon in retrospect following landmark studies in the 1990s. Only fair agreement exists in most studies for margin evaluation. Further, a trend towards lower concordance was noted for evaluating small masses. Classification into subdivisions 4a, 4b and 4c was more or less reproducible. Despite its limitations, most authors agree that stratification predicting the likelihood of malignancy could be useful for decision making and communication with patients, and between researchers, physicians and physicians of different specialties [14-17]. The updated second edition of BI-RADS® US (2011) will re-emphasize the importance of basic features, such as mass shape, margin and orientation on one hand, and associated findings as an adjunct on the other. The amended chapters cover expanded general issues, detailed lexicon images and US descriptors, reporting system and guidance. Fig. 3 presents a training schema for beginners in the field of breast diagnostics that can be used to learn standardized BI-RADS® US reading of larger masses. This schema has no scientific proof for use in daily work-up. Box 2 highlights some underlying intrinsic and extrinsic concepts of BI-RADS® US assessment categories that must be considered in daily work.

Concepts of Interpretation and Clinical Decision Making

The US characterization of a lesion in the daily routine follows a reproducible diagnostic algorithm and should involve fundamental US and all advanced applications of the used US system, preferably on a one-click basis.

First, the reader must define whether or not the lesion resembles a typical benign finding, such as cyst, lipoma, lymph node or previously know scar or fibroadenoma (Fig. 3). Complicated cysts with internal debris are challenging. When the debris is mobile or a fluid-debris level is seen, complicated cysts can be dismissed as benign findings, i.e. BI-RADS® US category 2 [11, 18].

Second, a typical oval-shaped, hypoechoic lesion with circumscribed margins and horizontal orientation in young women is most likely a fibroadenoma (Fig. 4). Short-term follow-up can be used. Several studies concluded that short-term follow-up of such BI-RADS® US category 3 lesions is associated with a cancer rate <2% [19-21]. Being older than 45 years, palpability or any preselection that enriched cancer cases in the collective is associated with cancer rates >2%. In a recent study, 0.8% of 4,000 women with lesions that were initially classified as probably benign proved to be malignant at follow-up. The most frequent reason for a false-negative assessment on US was failure to recognize suspicious margin characteristics (28 of 32 malignancies, 87.5%). Malignancy was more frequent in palpable (2.4%, 21 of 859) than nonpalpable lesions (0.4%, 11 of 3,141) [22]. As an isolated finding, homogeneous complicated cysts and clustered microcysts can be classified as probably benign, particularly if the lesion is new or rather small or deep, i.e., diagnostic uncertainty exists [18].

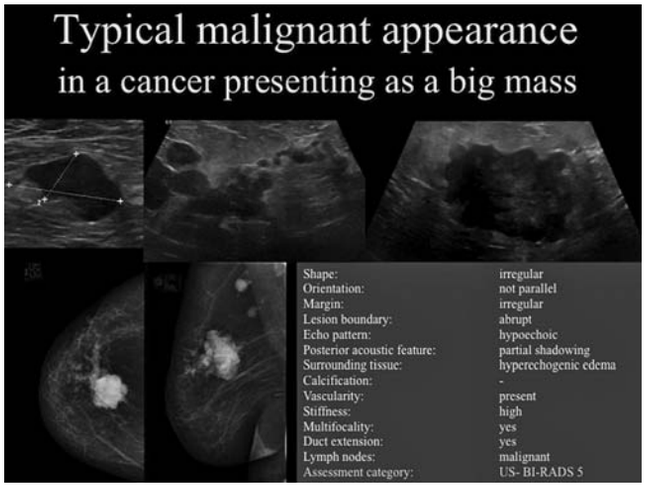

Fig. 4. Typical malignant appearance of ductal invasive cancer presenting as a lump in a 70-year-old patient. Mammography and ultrasound present the tumorous irregular mass, branching pattern of ductal extension, multifocal lesions, and axillary lymph node metastasis showing an expanded cortex. Description is given for the biggest mass following ultrasound Breast Imaging Reporting and Data System

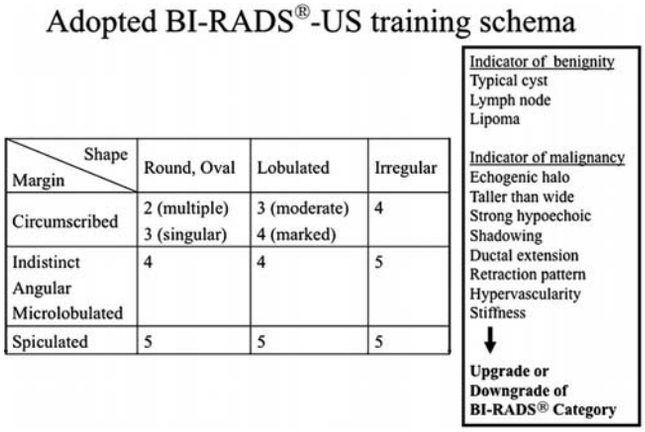

Fig. 5. Adopted Breast Imaging Reporting and Data System ultrasound (BI-RADS US) training schema. BI-RADS characterization of a mass can be taught using basic descriptors and associated findings that upgrade or downgrade the overall assessment category. The teaching should support beginners in the field of breast diagnosis. This schema provides no scientific proof for use in daily workup, as it can miss cancers

Third, detailed analysis of US morphology, vascularity and elasticity of a lesion should disclose any suspicious basic descriptor or suspicious associated finding. The presence of suspicious descriptors results in a BI-RADS® US category 4 or 5 depending on the total number and character of these descriptors. A biopsy is recommended in these cases and also in benign-looking lesions that significantly increase in size during follow-up (Fig. 5) [11].

Updated Role of Ultrasound, Including Interventions

US studies in up to 12,000 asymptomatic patients yielded tumor detection rates of only 0.3-0.4 %; however, a similar size and stage was reported compared with mammographically detected clinically occult cancers. The advantage of US as an adjunct to mammography is greatest in women with palpable lesions and those at high risk, including women with dense breasts, which is a risk factor. The US signs of malignancy develop with increasing tumor size. No single diagnostic sign can pick up all cancers due to their heterogeneous appearance (Fig. 6). Patients with a high mammographic density (>75%) present in meta-analysis with fourfold increased risk compared with women with low radiodense breasts, and a twofold increased risk compared with women with scattered fibroglandular breasts [7]. The sensitivity of standard US for breast cancer varies from 55% to 95%. US transfers an additional diagnostic yield of 30-40% in comparison with mammography to patients with radiodense breasts in the incidence setting (Fig. 5). The updated ACR Imaging Network (ACRIN) follow-up study focuses on cancer

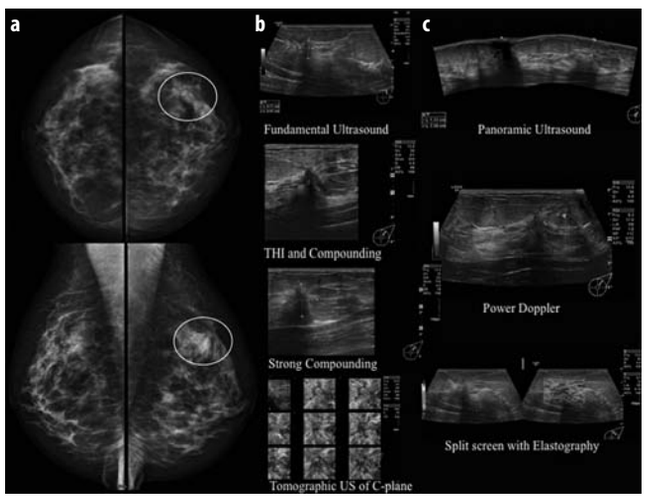

Fig. 6 a-c. A 48-year-old patient presenting with an architectural distortion in mammography (**a**). Corresponding mass could be missed using fundamental ultrasound (US) only. Advanced US modes (**b**, **c**) clearly show a mass with speculations, retraction pattern in 3D US, associated flow, and moderate stiffness. Histology was ductal invasive cancer (*G1*). *THI*, tissue harmonic imaging (for color reproduction see p 344)

detection in patients with increased risk due to radiodense breasts, under surveillance after breast cancer or other conditions. Of 100 imaging-detected cancers, 23 cancers have been found only by mammography, 22 by US only, 26 by both methods, and 9 by MRI only. In national screening programs, mammography is still the method of choice for early breast cancer detection. The upcoming Austrian national screening program will add US in all women presenting with an ACR density level 3 and 4 (dense and extremely dense). To date, mammography still

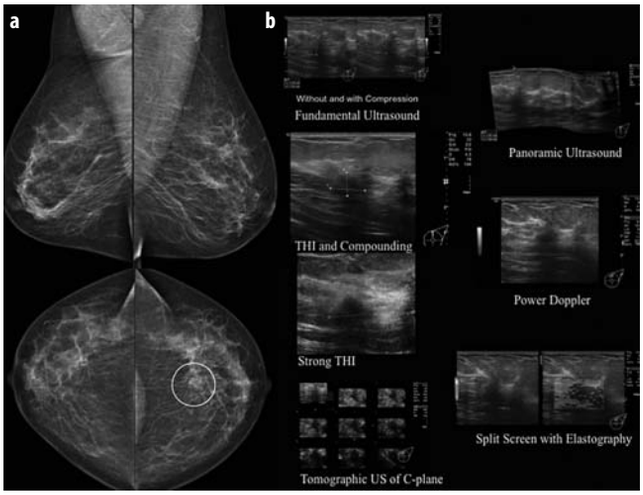

Fig. 7 a, b. A 47-year-old woman with mammographic mass (**a**) at 12 o'clock and corresponding ultrasound (US) (**b**) lesion presenting as an irregular hypoechoic mass, with strong shadowing, poor vascularity, and stiffness (*blue* low strain in the strain elastography image). Histology was ductal invasive cancer with low proliferation fraction. *THI,* tissue harmonic imaging (for color reproduction see p 345)

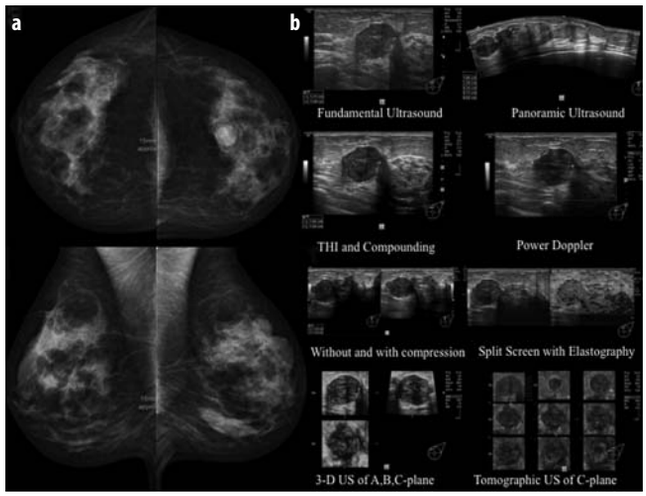

Fig. 8 a, b. A 51-year-old woman presenting with a recurrent mass following incomplete resection of a fibroadenoma using vacuum-assisted biopsy (VAB) 2 years earlier. Mammography shows a circumscribed round mass (**a**). Ultrasound (**b**) presents a correlative oval mass, adjacent scar with strong shadowing due to former VAB, and a second lesion. Both lesions show low vascularity and intermediate elasticity. Histology of both lesions showed fibroadenomas abundant with cells and regressive changes. *THI,* tissue harmonic imaging (for color reproduction see p 345)

provides the best compromise between advantages, disadvantages and costs [23, 24]. Breast US is indicated for further assessment of mammographic abnormalities and guiding minimally invasive biopsy. Masses in mammography and on MRI can be correlated with US confidently with increasing size, starting at a diameter of 0.5 cm [25-27]. Although advanced US is suitable for detecting subtle changes of DCIS, the detection rate of DCIS by US is low without prior knowledge of focal DCIS at mammography. Targeted US of suspected DCIS frequently finds hypoechoic lesions that represent dilated TDLUs and look similar to them, such as fibroadenoma, papilloma, ductectasia or microcystic changes. US is the method of choice when assessing and puncturing such solid-looking small masses, dilated ducts, pseudomicrocystic lesions or dense accumulations of microcalcifications that corresponded with mammographic changes. A radiogram of large-core cylinders is mandatory to correlate the US finding with index calcifications [3]. Underestimation of US-guided 14 G large core needle biopsy (LCNB) in comparison with VAB is an unsolved problem in the preoperative diagnosis of DCIS compared with the golden standard of surgical excision. Therefore, such patients rather should be directed towards VAB rather than LCNB. Underestimation rates in DCIS are reported to be between 9% and 16% for VAB, and 22% and 48% for LCNB [3, 27, 28]. For localization of nonpalpable breast cancer, intraoperative US is a reliable alternative to guide wire localization, as it achieves similar results in terms of complete tumor removal (93%), re-excision rate (11%) and excised volume [29]. Intraoperative breast US can guide segmental surgery with wide distances to the malignant lesions. High-resolution US shows a comparable diagnostic performance in preoperative staging with MRI in invasive ductal cancer. MRI performs better in preoperative staging of lobular invasive cancer, DCIS, multifocality, multicentricity and posterior breast-wall involvement, as well as diagnosing recurrence, failing silicon prosthesis and monitoring during neoadjuvant therapy. The median additional detection yield for MRI is estimated as 16% in meta-analyses. To date, there is no evidence that preoperative MRI improves surgical care or prognosis [30-32]. The analogous statement is probably true for the role of US in preoperative staging. The presence of Doppler blood flow increases the malignancy pick-up rate, but at the expense of a significant decrease in specificity and diagnostic accuracy, and an increase in biopsy rate prognosis [33]. Contrast-enhanced US (CEUS) does not appear to be superior to conventional US as a diagnostic tool overall; however, it is a very rarely used adjunct, with no role in daily routine work. The overall true-positive rates for conventional US and CEUS have been found to be 88% and 86%, respectively. DCIS, medullary carcinoma, and intraductal papillary carcinoma achieved improved true-positive rates with 94%, 100% and 100%, respectively [34]. Elastography can increase the specificity of the US examination. Two recent meta-analyses on strain elastography reported summary sensitivities of 88% and 83%, and specificities of 83% and 84% [35, 36]. Also, several studies based on shear wave elastography have shed light on the old experience that soft should be benign and stiff resembles malignancy. In BI-RADS® 4a and 3 US lesions, the certainty of benignity is increased in an elastographic very soft lesion [37]. In contrast, the presence of an elastographic very stiff malignant lesion is

associated with poor prognosis measured by histologic parameters [38]. All elastographic techniques aim to characterize breast lesions that have been previously detected and categorized according to BI-RADS® by real-time US. Therefore, the role of elastography in its various applications resembles an additional characterizing tool, such as Doppler. It has no role in population-based breast cancer screening or primary detection of US lesions. In summary, elastography will enter clinical routine and, in combination with Doppler, will increase the potential of advanced US to better characterize breast lesions.

Automated breast US acquires data of the 3D breast volume that can be analyzed on a workstation subsequent to the examination. This technology has the potential to develop US to a become a primary screening tool and seems to show similar potential in characterizing lesions according to BI-RADS® US, at similar or slightly reduced diagnostic accuracy [39, 40].

Sentinel lymph node (SLN) biopsy is associated with a low local recurrence and similar survival rates to axillary lymph node dissection, and is now the standard of care. All patients with invasive breast cancer should have US of the axilla to exclude obvious nodal local spread. The presence of asymmetric focal hypoechoic cortical lobulations >3 mm, or a completely hypoechoic node with US, should direct further examination to fine-needle aspiration of the index lymph node. Cortical thickness greater than 3 mm reveals an increased risk of approximately four times for the presence of an axillary lymph node metastasis, as compared with cortical thickness less than 3 mm. Further, the absence of a hilum shows the highest specificity for axillary lymph node metastasis (94.6%), but low sensitivity [41]. US-guided biopsy of axillary lymph nodes has a sensitivity that varies between 30.6% (22.5-39.6%) and 62.9% (49.7-74.8%), and a specificity of 100% (94.8-100%) [42]. When the cytological or histological finding is positive, SLN biopsy can be omitted and primary axillary lymph node dissection be performed. In negative US findings, SLN biopsy should be performed due to the substantial number of false-negative results in patients with invasive breast cancer, although preoperative axillary US alone may exclude most cases of N2 and N3 disease [43, 44].

HRUS provides additional diagnostic information compared with mammography in postoperative surveillance after breast-conserving and oncoplastic surgery. MRI would be the method of choice for surveillance with respect to its better diagnostic performance in comparison with mammography and US [45]. However, costs and availability restrict the use of MRI to high-risk patients and differentiation between scar and recurrence with a problematic diagnostic background presented by the other modalities. Most surveillance guidelines rely on mammography alone or mammography in combination with US. To detect one locoregional recurrence or second primary breast cancer preclinically, 1,349 physical examinations versus 262 mammography and/or MRI tests were performed. Follow-up provided by only one discipline might decrease the number of unnecessary follow-up visits. Breast imaging plays a major role and physical examination a minor role in the early detection of second primary breast cancers and locoregional recurrences. The ability of physical examination to detect relapses early is low and should therefore be minimized.

Summary

Modern breast care requires definitive nonoperative diagnosis of all potential breast abnormalities in a timely and cost-effective way. US-guided CNB has become the minimal invasive biopsy method of choice for all breast lesions (sensitivity 93-98 %; specificity 95-100%). US-guided VAB is increasingly being used for diagnosing borderline lesions, for complete preoperative staging in patients with extensive ductal component, and for therapeutic excision of biopsy-proven benign lesions, such as fibroadenomas and some papillary lesions and radial scars. The diagnostic accuracy of US-guided VAB for invasive cancers is close to 100% [3, 25, 27].

References

1. Mundinger A (2011) Ultrasound of the breast including interventions: an update. In Hodler J, von Schulthess GK, Zollikofer CH L (Eds) Diseases of the heart, chest and breast 2011-2014. Springer-Verlag Italy, Milano, pp 259-266
2. Teboul M (2010) Advantages of ductal echography (DE) over conventional breast investigation in the diagnosis of breast malignancies. Medical Ultrasonography 2:32-42
3. Weismann C, Mayr C, Egger H, Auer A (2011) Breast sonography -2D,3D,4D ultrasound or elastography? Breast Care 6: 98-103
2. Madjar H, Mendelson E (2008) The practice of breast ultrasound, 2nd edn. Thieme, Stuttgart, New York, pp 23-69
3. Mundinger A, Wilson ARM, Weismann C et al (2010) Breast ultrasound − update. EJC Supplements 8:11-14
4. Weismann C, Hergan K (2007) Current status of 3D/4D volume ultrasound of the breast. Ultraschall Med 28:273-282
5. ACR (2009) Practice guideline for the performance of ultrasound-guided percutaneous breast interventional procedures. Revised 2009. http://www.acr.org/SecondaryMainMenuCategories/quality_safety/guidelines/breast/us_guided_breast.aspx
6. American College of Radiology (ACR) (2009) Practice guideline for the performance of stereotactically guided breast interventional procedures. Revised 2009. http://www.acr.org/SecondaryMainMenuCategories/quality_safety/guidelines/breast/stereotactically_guided_breast.aspx
7. McCormack VA, Dos Santos Silva I (2006) Breast density and parenchymal patterns as markers of Breast Cancer Risk: A Meta-analysis. Cancer Epidemiol Biomarkers Prev15:1159-1169
8. Heywang-Köbrunner SH, Schreer I, Heindel et al (2008) Imaging studies for the early detection of breast cancer. Dtsch Arztebl Int 105:541-547
9. Madjar H, Rickard M, Jellins J et al (1999) IBUS guidelines for the ultrasonic examination of the breast. Eur J Ultrasound 9:99-102
10. Khouri NF (2009) Breast ultrasound. In: Harris J, Morrow M, Lippman M, Osborne C (Eds) Diseases of the breast, 4th edn. Wolter Kluwer, Lippincott Williams & Wilkins, Philadelphia, PA, pp 131-151

11. American College of Radiology (ACR) (2003) ACR BI-RADS® – Ultrasound. In: ACR Breast Imaging Reporting and Data System, Breast imaging atlas. American College of Radiology, Reston VA
12. Madjar H, Ohlinger R, Mundinger A et al (2006) BI-RADS-analogue DEGUM criteria for findings in breast ultrasound - consensus of the DEGUM Committee on Breast Ultrasound. Ultraschall Med 27(4):374-379
13. Wojcinski S, Farrokh A, Weber S et al (2010) Multicenter study of ultrasound real-time tissue elastography in 779 cases for the assessment of breast lesions: improved diagnostic performance by combining the BI-RADS®-US classification system with sonoelastography. Ultraschall Med 31:484-91
14. Lazarus E, Mainiero MB, Schepps et al (2006) BI-RADS lexicon for US and mammography: interobserver variability and positive predictive value. Radiology 239:385-91
15. Lee HJ, Kim EK, Kim MJ et al (2008) Observer variability of Breast Imaging Reporting and Data System (BI-RADS) for breast ultrasound. Eur J Radiol 65:293-298
16. Santana Montesdeoca JM, Gómez Arnáiz A, Fuentes Pavón R et al (2009) Diagnostic accuracy and interobserver variability in the BI-RADS ultrasound system. Radiologia 51:477-486
17. Abdullah N, Mesurolle B, El-Khoury M et al (2009) Breast imaging reporting and data system lexicon for US: interobserver agreement for assessment of breast masses. Radiology 25:2665-2672
18. Berg WA, Sechtin AG, Marques H et al (2010) Cystic breast masses and the ACRIN 6666 experience. Radiol Clin North Am 48:931-987
19. Gruber R, Jaromi S, Rudas M et al (2012) Histologic work-up of non-palpable breast lesions classified as probably benign at initial mammography and/or ultrasound (BI-RADS category 3). Eur J Radiol [Epub ahead of print]
20. Fu CY, Hsu HH, Yu JC et al (2010) Influence of Age on PPV of Sonographic BI-RADS Categories 3, 4, and 5. Ultraschall Med 32:8-13
21. Moon HJ, Kim MJ, Kwak JY et al(2010) Probably benign breast lesions on ultrasonography: a retrospective review of ultrasonographic features and clinical factors affecting the BI-RADS categorization. Acta Radiol 51:375-382
22. Moon HJ, Kim MJ, Kwak JY et al (2010) Malignant lesions initially categorized as probably benign breast lesions: retrospective review of ultrasonographic, clinical and pathologic characteristics. Ultrasound Med Biol 36:551-559
23. Berg WA, Zhang Z, Lehrer D et al ACRIN 6666 Investigators (2012) Detection of breast cancer with addition of annual screening ultrasound or a single screening MRI to mammography in women with elevated breast cancer risk.JAMA 07:1394-404
24 El Saghir NS, Anderson BO (2012) Breast cancer early detection and resources: where in the world do we start? The Breast 21:423-425
25. Mundinger A (2006) Staging the breast and axilla. EJC Supplements 4:35-37
26. Lehman CD, DeMartini W, Anderson BO et al (2009) Indications for breast MRI in the patient with newly diagnosed breast cancer. J Natl Compr Canc Netw 7:193-201
27. Cho N, Moon WK, Cha JH et al (2009) Ultrasound-guided vacuum-assisted biopsy of microcalcifications detected at screening mammography. Acta Radiol 50:602-609
28 Suh YJ, Kim MJ, Kim EK et al (2012) Comparison of the underestimation rate in cases with ductal carcinoma in situ at ultrasound-guided core biopsy: 14-gauge automated core-needle biopsy vs. 8- or 11-gauge vacuum-assisted biopsy. Br J Radiol 85:e349-56
29 Barentsz MW, van Dalen T, Gobardhan PD et al (2012) Intraoperative ultrasound guidance for excision of non-palpable invasive breast cancer: a hospital-based series and an overview of the literature. Breast Cancer Res Treat 135:209-219
30 Houssami N, Hayes DF (2009) Review of preoperative magnetic resonance imaging (MRI) in breast cancer: should MRI be performed on all women with newly diagnosed, early stage breast cancer? CA Cancer J Clin 59:290-302
31 Turnbull L, Brown S, Harvey I et al (2010) Comparative effectiveness of MRI in breast cancer (COMICE) trial: a randomised controlled trial. Lancet 375:563-571
32 Peters NH, van Esser S, van den Bosch MA et al (2011) Preoperative MRI and surgical management in patients with non-palpable breast cancer: the MONET - randomised controlled trial. Eur J Cancer 47:879-886
33 Tozaki M, Fukuma E (2011) Does power Doppler ultrasonography improve the BI-RADS category assessment and diagnostic accuracy of solid breast lesions? Acta Radiol 52:706-710
34 Wang X, Xu P, Wang Y, Grant EG (2011) Contrast-enhanced ultrasonographic findings of different histopathologic types of breast cancer. Acta Radiol 52:248-255
35 Sadigh G, Carlos RC, Neal CH, Dwamena BA (2012) Ultrasonographic differentiation of malignant from benign breast lesions: a meta-analytic comparison of elasticity and BIRADS scoring. Breast Cancer Res Treat 133:23-35
36 Gong X, Xu Q, Xu Z et al (2011) Real-time elastography for the differentiation of benign and malignant breast lesions: a meta-analysis. Breast Cancer Res Treat 130:11-18
37 Berg WA, Cosgrove DO, Doré CJ et al for the BE1 Investigators (2012) Shear-wave elastography improves the specificity of breast US: the multinational study of 939 masses. Radiology 262:435-449
38 Evans A, Whelehan P, Thomson K (2012) Invasive breast cancer: relationship between shear-wave elastographic findings and histologic prognostic factors. Radiology 263:673-677
39 Prosch H, Halbwachs C, Strobl C et al (2011) Automated breast ultrasound vs. handheld ultrasound: BI-RADS classification, duration of the examination and patient comfort. Ultraschall Med 32:504-10
40 Giuliano V, Giuliano C (2012) Improved breast cancer detection in asymptomatic women using 3D-automated breast ultrasound in mammographically dense breasts. Clin Imaging. [Epub ahead of print]
41 Choi YJ, Ko EY, Han BK et al (2009) High-resolution ultrasonographic features of axillary lymph node metastasis in patients with breast cancer. Breast 18:119-122
42 Alvarez S, Añorbe E, Alcorta P et al (2006) Role of sonography in the diagnosis of axillary lymph node metastases in breast cancer: a systematic review. AJR Am J Roentgenol 186:1342-1348
43 Choi JS, Kim MJ, Moon HJ et al (2012) False negative results of preoperative axillary ultrasound in patients with invasive breast cancer: correlations with clinicopathologic findings. Ultrasound Med Biol 38:1881-1886
44 Cody HS 3rd, Houssami N (2012) Axillary management in breast cancer: what's new for 2012? Breast 21:411-415
45 Pan L, Han Y, Sun X, Liu J et al (2010) FDG-PET and other imaging modalities for the evaluation of breast cancer recurrence and metastases: a meta-analysis. J Cancer Res Clin Oncol 136:1007-1022