High-quality Breast Ultrasonography

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INTRODUCTION

Ultrasonography is an important imaging modality for the detection and characterization of lesions in the breast. Appropriate indications for breast ultrasonography as recommended by the American College of Radiology Practice Guidelines include the following:

- Evaluation and characterization of palpable masses and other breast-related signs and/or symptoms
- Evaluation of abnormalities detected on mammography or breast magnetic resonance (MR) imaging
- Determining the method of guidance for percutaneous biopsy
- Supplemental screening to mammography in certain populations

Advantages of breast ultrasonography include that it is a rapid, widely available, and inexpensive modality that does not involve breast compression or ionizing radiation. As with all imaging modalities, ultrasonography’s value in the detection and characterization of breast lesions largely depends on the quality of the images. Ultrasonography is highly operator dependent, and erroneous conclusions may be caused by technique or the application or misapplication of image processing algorithms. Although there have been advances in ultrasonography, including the development of three-dimensional transducers and automated whole-breast systems, breast ultrasonography still requires real-time imaging in many situations for accurate interpretation.

In recent years, multiple states have passed legislation mandating that women with dense breasts be notified of their breast density and that they may benefit from supplemental screening. This development has led to the proliferation of whole-breast screening ultrasonography as a supplemental screening modality to mammography in women with dense breasts. Particularly when ultrasonography is used in the screening setting, it is imperative to understand the various technical factors affecting image optimization in order to maximize sensitivity while reducing the number of unnecessary biopsies and recommendations for short term follow-up studies. This article reviews the technical factors that should be considered in order to perform high-quality breast ultrasonography.

PATIENT POSITIONING

The optimal position of the patient should minimize the thickness of the portion of the breast being imaged. During breast ultrasonography, the patient should be positioned with the ipsilateral arm over the head. In general, medial lesions should...
be scanned with the patient in the supine position, whereas lateral lesions should be scanned with the patient in a supine oblique position in order to reduce the thickness of the breast.

**TRANSDUCER SELECTION**

High-quality breast ultrasonography begins with selection of an appropriate transducer. The transducers used in breast imaging must have a high frequency (between 10 and 15 MHz) because of the superficial nature of the breast and the need to resolve small structures (Fig. 1). However, higher frequency sound waves are more strongly attenuated by tissue than lower frequency waves. Therefore there is a trade-off between higher resolution and reduced penetration. With proper positioning and the patient in the supine or supine oblique position, most breasts are only a few centimeters thick and high-frequency transducers provide optimum image quality for all of the breast tissue. When evaluating deep tissue in patients with particularly large breasts, it may be helpful to have lower frequency transducers available to be used only in this specific situation.

Bandwidth is another consideration in transducer selection. The bandwidth is the spread of frequency around the central frequency of the transducer, and transducers with a broader bandwidth have improved resolution. Transducers used in breast imaging may either be linear or matrix array, which affects image resolution.

**IMAGE RESOLUTION**

The goal of equipment selection is to maximize image resolution, which is the ability to distinguish structures that are close together as separate lesions. Image resolution is composed of contrast and spatial resolution (Fig. 2). Optimal contrast resolution is necessary to differentiate subtle lesions from the surrounding breast tissue, and these lesions may have subtle variations of gray scale. Transducers with higher frequencies have improved contrast resolution.

Spatial resolution is composed of both axial and lateral resolution. Axial resolution is the ability to resolve structures along the axis of the ultrasound beam or the Z plane (the depth). Axial resolution depends on pulse length, which is determined by the frequency and the bandwidth of the transducer. A transducer with a higher frequency and a broader bandwidth has a shorter wavelength and pulse length relative to a lower frequency transducer, which improves axial resolution.

Lateral resolution is the ability to resolve structures in the X and Y planes that are at the same depth. Lateral resolution is related to the transducer beam width, and lateral resolution is not adequate when lesions positioned side by side are within the same beam width. Because a higher frequency transducer has a narrower beam width relative to a lower frequency transducer, lateral resolution is improved.

**FOCAL ZONE**

As discussed earlier, lateral resolution is related to the beam width. In addition to selecting a high-frequency transducer to maintain a narrow beam width, the beam width can be further reduced by adjusting the focal zone.

Linear array transducers have multiple piezoelectric crystals or elements arranged side by side. If a single element is used to both transmit and receive the signal, the beam diverges quickly after traveling a few millimeters, resulting in poor lateral resolution because of beam divergence. Linear array transducers pulse adjacent elements simultaneously as a single element group to overcome beam divergence and then in succession to form the image. Delaying the timing of firing of elements within a single element group adjusts the focal zone so that the beam is narrowed along the long-axis plane. The specific time delay

![Fig. 1. Transducer frequency.](image)

High-quality breast ultrasonography requires the use of high-frequency transducers. The same mass (arrows) is imaged using 9-MHz (A) and 12-MHz (B) transducers. The higher frequency (12 MHz) transducer results in better detail of the mass and the surrounding breast parenchyma.
determines the depth of focus for the transmitted beam. Matrix array transducers, which have multiple rows of elements, allow focusing in both the short and long axes. The focal zone represents the narrowest part of the beam and is the area where lateral resolution is optimized. Therefore the focal zone should be placed at or slightly below the area of interest (Fig. 3). Because of transducer limitations, even the shallowest focal zone setting may not achieve the narrowest beam width possible for lesions near the skin. Therefore a standoff pad may be required to improve resolution (Fig. 4).

DEPTH

During an initial survey, the depth on the ultrasonography image should be set so that the breast parenchyma is imaged to the pectoralis muscle, which should be along the far field of view (Fig. 5). Once a finding is identified, the depth may be adjusted.

GAIN AND TIME GAIN COMPENSATION

The overall gain control provides uniform amplification of all echo signals returning to the transducer, compensating for increased attenuation of the ultrasound beam as it penetrates deeper into the tissues. Increasing the gain amplifies the intensity of all signals returning to the transducer so that the image is brighter and more visible on the display screen.

The initial gain setting should be adjusted so that the subcutaneous fat is a medium level of gray. Lesions may be mischaracterized if the gain is inappropriately set. For example, a subcentimeter hypoechoic solid mass or a complicated cyst can mimic a simple anechoic cyst if the gain is set too low (Fig. 6). In contrast, by inappropriately setting the gain too high, a simple or complicated cyst may appear solid.

Unlike the gain, which adjusts all signals returning to the transducer, the time gain compensation (TGC) function allows selective amplification of weaker signals from areas deeper in the breast. The TGC should be set so that all echoes from similar structures are displayed with the same brightness from the near to far field. For example, the subcutaneous fat should be the same shade of medium gray as the retromammary fat.

SPATIAL COMPOUND IMAGING

With standard imaging, the ultrasound pulses are propagated perpendicular to the long axis of the transducer. Spatial compounding uses electronic beam steering to obtain multiple images at different angles, which are then combined to form a single image in real time. Spatial compounding enhances returning echoes from real structures, thereby improving image resolution, so that image features such as lesion margins may be better characterized. Artifacts, such as posterior acoustic enhancement characteristic of simple cysts and posterior shadowing seen with some solid masses, tend to be averaged out and reduced. However, some small cancers are detected primarily because of their posterior acoustic shadowing. When scanning for a subtle...
lesion, it may be beneficial to use standard ultrasonography imaging, in which the posterior shadowing may help identify the lesion, and then apply spatial compound imaging for analysis once the lesion has been detected.

**HARMONIC IMAGING**

Harmonic imaging is another signal processing technique to improve contrast and lateral resolution and reduce artifacts. Harmonic imaging applies a filter to remove image harmonics, which are multiples of the transmitted frequency. This technique is advantageous because much of the artifact degrading image resolution is contained within the lower frequency components of the beam (Fig. 7).

**COLOR DOPPLER AND POWER DOPPLER**

Tumor angiogenesis plays a fundamental role in local tumor growth, invasion, and progression to metastases. As tumors outgrow their native blood supply, hypoxia ensues, which induces expression of multiple angiogenic factors such as vascular endothelial growth factor. These factors induce the growth of existing capillaries and the formation of abnormal vessels that are often tortuous and disordered, which may be seen on color Doppler. Power Doppler imaging may be used to increased sensitivity compared with color Doppler in detecting small vessels and low flow.

The presence or absence or type of tumor vascularity alone is not sufficient to characterize a lesion as benign or malignant. Features suggesting malignant lesions include hypervascularity, irregular branching central vessels, and more than one vascular pole. Demonstrating internal vascularity within a sonographic lesion confirms that it is either solid or at least contains a solid component. Doppler imaging is most useful in distinguishing a high-grade invasive cancer or metastatic lymph node, both of which can appear anechoic, from a simple or complicated cyst (Fig. 8). Color Doppler may also be useful in differentiating between debris within a duct and an intraductal mass.

When using Doppler imaging, it is important to apply light transducer pressure to prevent occlusion of slow flow within vessels. The position and size of the color box should also be focused to the lesion of interest to maximize sensitivity to flow.

**REAL-TIME IMAGING**

Real-time imaging may be essential for accurate interpretation in many situations. In patients with palpable complaints, real-time ultrasonography by

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**Fig. 4.** Focal zone of superficial lesion. Because of transducer limitations, even the shallowest focal zone setting may not achieve the narrowest beam width possible for lesions near the skin. Therefore a standoff pad may be required to improve resolution. (A) A superficial hypoechoic mass (arrow). With the use of a standoff pad (B) allowing optimal resolution at the level of the skin, a skin tract (arrow) is now seen, confirming the diagnosis of a benign sebaceous cyst.

**Fig. 5.** Depth. The depth should be set so that the image focuses on the area of interest without including the lung, which provides no useful information (A). When the depth is set appropriately (B), the features of the mass (arrows) are better seen.
the interpreting radiologist may be prudent in cases in which initial scanning by the technologist does not identify an abnormality. Another situation in which real-time imaging may be important is when differentiating between mobile debris in a complicated cyst versus a complex cystic mass (Fig. 9).

**TARGETED ULTRASOUND: LESION CORRELATION**

Targeted ultrasonography is often performed in order to identify a sonographic correlate to an abnormality identified on mammography or breast MR imaging before percutaneous biopsy. Ultrasonography-guided biopsy is the method of choice to sample any finding that is sonographically evident. Compared with stereotactic or MR imaging–guided biopsy, ultrasonography-guided biopsy is faster, more comfortable for the patient, and allows greater access to breast tissue, especially for far posterior and medial lesions that may not be amenable to either stereotactic or MR imaging–guided biopsy. In addition, adequate sampling is more consistently obtained because the needle can be seen traversing the target in real time.

When targeted ultrasonography is performed to evaluate a mammographic finding, careful triangulation of lesion location should be performed. Adjustments should be made when using cranio-caudal and mediolateral-oblique (MLO) views to determine the clock axis for targeted ultrasonography. The location of the lesion may be higher or lower than expected based on the MLO view for medial and lateral lesions respectively. In addition, careful attention should be paid to both lesion depth

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**Fig. 6.** Gain. Lesions can be mischaracterized if the gain is set too low or too high. (A) The gain is set too low and the lesion appears anechoic (arrow), suggesting a simple cyst. With the gain set correctly (B), low-level internal echoes (arrow) are now seen in this complicated cyst. (C) The gain is set too high, creating artificial internal echoes (arrow) mimicking a solid mass. When the gain is corrected (D), the lesion is seen to be a simple cyst (arrow).

**Fig. 7.** Harmonic imaging. (A) The 12:00 axis of the right breast shows 2 subtle structures (arrow) that appear almost isoechoic to the fat. (B) Harmonic imaging of the same area allows better delineation of the margins and internal features (arrow), which allows the two lesions to be characterized as complicated cysts.
and the surrounding anatomic landmarks. The patient is positioned differently during breast ultrasonography, MR imaging, and mammogram, which affects lesion location. A superficial mass at the fat-gland interface on mammography or MR imaging should also be at that interface on targeted ultrasonography (Fig. 10). Other findings such as an adjacent cyst or dilated duct may also be used as anatomic landmarks.

When sampling a potential sonographic correlate to a mammographic abnormality, a localizing clip should be placed in the biopsied lesion using ultrasonography guidance. A postbiopsy mammogram should be obtained to confirm correlation between the biopsied lesion and the mammographic abnormality.

Targeted ultrasonography is often performed to evaluate for a sonographic correlate to an MR imaging finding in order to facilitate biopsy. A potential correlate is more frequently identified for enhancing masses compared with nonmass enhancement. However, true ultrasonography–MR imaging correlation can only be confirmed if follow-up MR imaging is performed, showing the localizing clip placed at the time of ultrasonography-guided biopsy within the area of enhancement on MR imaging. In one study, the presumed sonographic correlate biopsied yielding a benign, concordant diagnosis did not correspond with the lesion originally detected on MR imaging in 12% of cases. For this reason, 6-month follow-up MR imaging is recommended following benign concordant biopsy of a sonographic correlate to an MR imaging–detected lesion.

**Fig. 8.** Color Doppler. (A) A hypoechoic mass (arrow) in the far field with posterior enhancement, possibly representing a complicated cyst. With color Doppler (B), vascularity (arrow) is seen within the mass, confirming that it is solid and not a complicated cyst. Biopsy yielded invasive ductal carcinoma.

**Fig. 9.** Real-time imaging. (A) In the right breast at the 6:30 axis is a cyst with a possible intracystic mass (arrow). (B) When the patient is rolled into the left lateral decubitus position, the questionable mass moves into the dependent portion of the cyst (arrow), consistent with mobile debris.
images. The center frequency of the transducer must be at least 10 MHz. Unlike breast MR imaging accreditation, in which images from each individual magnet must be submitted, a facility must only provide a single example of a cyst and solid mass in the breast for ultrasonography accreditation regardless of the number of ultrasonography units at that facility. Two orthogonal mammographic views must be submitted with the lesion circled and visible on both views. Sonographic clinical images include the cyst and solid mass on 2 orthogonal views without calibers, and 1 image with appropriate measurements. Images should be taken along the longest axis of a lesion and then an orthogonal image. The longest axis of the lesion is not necessarily in the radial or antiradial plane, but may be in an oblique position. Criteria for a simple cyst include anechoic, circumscribed margin, and posterior enhancement. For submitted images of cysts, spatial compound imaging should be avoided if the resulting image fails to show posterior enhancement.

SUMMARY

Ultrasonography is an important modality that is frequently used in all aspects of breast imaging, including breast cancer screening, the evaluation of palpable abnormalities, further characterization of lesions seen mammographically, and for determining the method of percutaneous biopsy. Understanding the basic technical aspects of ultrasonography equipment is critical to ensure high breast ultrasonography image quality.

REFERENCES