Basics of Ultrasound Imaging
How to Optimize Your Machine and Technique

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A good ultrasound (US) scanner and a careful examination technique are prerequisites for a good-quality breast US examination. However, US scanners are now bundled with a growing number of “bells and whistles,” some of which not only are unnecessary for breast imaging but also may have a negative effect on image quality. The purpose of this lecture is to sort out the useful and indispensable techniques from completely useless techniques through examples of diagnostic pitfalls and errors, and to provide solutions to avoid these problems.

Transducers

US equipment used for breast imaging includes very high-frequency and matrix linear transducers that operate at peak frequencies of up to 18 MHz. Such transducers now allow visualization of cancers as small as a few millimeters. However, the penetration of these very high-frequency transducers is limited to 2 to 3 cm—even after electronically lowering the central frequency of the probe—and large breasts or large lesions cannot be fully imaged with these probes. It is therefore highly recommended to purchase another linear-array transducer of lower frequency. On occasion, only an abdominal-type, curved-array, low-frequency (2–5 MHz) probe may prove capable of imaging a very large breast or lesion.

“Extended-field-of-view” sonograms

The “extended-field-of-view” technology allows the operator to build a static picture with a field of view much wider than that available with standard real-time transducers. One advantage of obtaining sonograms of the entire breast is the ability to scan through a lesion and the nipple to measure the distance between the two for an optimal correlation with the location of

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the lesion on a mammogram.

Some high-end scanners have the capability to steer the beam electronically and to “expand” the rectangular field of view of the linear-array transducer into a trapezoidal one, thereby expanding the width of the field of view.

Power Doppler imaging

Color Doppler sonography (CDUS) was developed more than 30 years ago and was quickly improved with the advent of power Doppler imaging (PDUS). However, CDUS and more importantly PDUS remain widely ignored or underused by many breast imagers. Real-time high-frequency grayscale US and PDUS are the two tools required to perform an excellent breast US examination.

PDUS can demonstrate hypervascularity associated with inflammatory conditions (e.g., mastitis, cellulitis, abscesses) but, more importantly, it is used to map tumor-associated neovascularity. Because PDUS is one order of magnitude more sensitive than CDUS in the depiction of slow and low-volume flow, and because knowing the direction of flow is useless when evaluating masses or inflammation, PDUS should be preferred over CDUS in breast US. One exception is the use of the “twinkling artifact”—which is specific to CDUS—to detect small dense reflectors, including metallic tissue markers. Highly sensitive PDUS systems on recent scanners often allow differentiation between benign and malignant types of vascularity.

A simple, yet powerful application of PDUS is in differentiating between a rounded, markedly hypoechoic tumor and an inspissated cyst with low-level internal echoes. Detection of the smallest vessel within the lesion automatically excludes a cyst (or any other fluid collection) and confirms a neoplasm.

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This very simple yet very useful application of PDUS is still underused.

When searching for minimal intralesional flow signals, however, sonographers must be aware of the risk of obliterating small vessels with excessive pressure on the probe and therefore missing the opportunity of confirming a solid mass.

Real-time compound scanning

The principle of real-time compound scanning is to combine in real time the echoes obtained from multiple lines of sight emitted by a given transducer element in various oblique directions, compared with the single vertical parallel beams emitted by a standard linear-array transducer. The summation of the echoes from all of these crisscrossing beams was expected to improve the visibility of lesions, notably their lateral margins. However, the deleterious effects of this blurring have been quite obvious, including the removal of the “good” artifacts, i.e., those that are instrumental in establishing a sonographic diagnosis, including sound enhancement, shadowing, and comet-tail artifacts. This has led to the inability to see some minute lesions and the alteration of the appearance of others.

Breast imagers are strongly encouraged to turn this post-processing off to cancel the blurring, regain an excellent lateral resolution, and better see distal sound enhancement and comet tail artifacts.

Tissue harmonic imaging

Tissue harmonic imaging (THI), which slightly increases the spatial resolution and boosts the contrast, may improve the delineation of poorly defined lesions. It is also helpful for

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clearing cysts from spurious artifactual echoes that result from partial volume averaging. However, a major drawback of THI is that the substantial increase in contrast throughout the sonogram may create wide areas of shadowing, such as distal to a prominent Cooper's ligament, and these shadows may mimic an invasive lobular carcinoma. Therefore, it is critical to turn this option back off immediately after its use so that the next user of the machine will not be confused by the resulting over-contrasted images. THI should be used as an optional tool, not a default setting.

Three-dimensional (3D) US

3D US is not new. It has been proposed for addition to commercially available scanners since the mid-1980s. The theoretical benefit of 3D US is the reconstruction of scan planes that are otherwise impossible to obtain, especially coronal scan planes, which, according to a few authors, show the distorted architecture around cancers better than standard scan planes can. The major limitations are the time taken to render the 3D images and, more importantly, to navigate through the multiple additional possible oblique scan planes with the risk of becoming rapidly disoriented.

In fact, the experienced sonographer actually does a very fast 3D US rendering when he or she scans over a lesion in conventional 2D US because the brain quickly integrates the multiple 2D images to create a 3D rendering of the lesion's volume and shape.

A recent iteration of 3D US is whole-breast US scanning using an automated scanner (automated breast US or ABUS). The idea is far from new, however, and since the Octoson in the late seventies, investigators have struggled to develop an effective ABUS scanner. The recently proposed scanners are based on a single, very long, high-frequency linear-array transducer housed in a sizable pad that is manually applied to the breast. The transducer then scans over the breast for a few seconds, acquiring the breast volume dataset and displaying the images on the screen of a workstation.

Advantages include fast, automatic volume acquisition, which is an advantage for screening. However, correlation with mammograms remains limited owing to the differences in breast positioning between ABUS and mammography. Among other limitations is the fact that the device cannot scan the entire breast (especially if the breast is large) and that more than one volume acquisition is needed to ensure that the entire breast has been scanned. But the most significant disadvantage is the lack of real time and therefore the inability to perform a real-time dynamic examination. It is not possible to clear an area affected by an artifact (such as the shadowing from a prominent Cooper's ligament) to improve the visualization of a subtle finding by using a different position of the probe or scan plane, or to apply dynamic maneuvers such as graded compression with the probe (see below). US-guided needle biopsies are not possible. In addition, these devices have no Doppler capability and cannot be used to scan the axilla and other nodal basins that need to be examined in patients with breast cancer.

It has been proposed to have the patients scanned by the sonographer but to have images interpreted by the radiologist later in the day. However, disconnecting the radiologist from the actual US examination carries the risk of an exceedingly high number of recalls.

Portable laptop scanners

Today, laptop scanners offer nearly all the features of high-end scanners at a fraction of the cost and with the unique advantage of portability. They all now use high-frequency linear-

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array transducers and many offer THI, high-sensitivity PDUS, and even the extended field of view capability.

Good-quality breast US is now feasible with high-end laptop scanners. At MD Anderson, a portable scanner is used to examine patients at bedside to rule out breast abscesses or other fluid collections in the immediate postoperative setting and also for intraoperative localization of nonpalpable masses.

Elastography

The goal of elastography is to provide information about the stiffness (or elasticity) of tissues. Elastography has recently become a very popular topic in the radiology community. US elastographic techniques can rely on the compression of the tissues (strain techniques) or on the generation of shear waves and the measurement of shear-wave velocity through the tissues (shear-wave techniques). Very few evidence-based non-industry-sponsored studies have reported a diagnostic added value of elastography. In fact, a sensitivity of 82% in the diagnosis of breast cancer has been reported for elastography compared with 94% for conventional grayscale US. More recently, it has been shown that the overall diagnostic performance of US plus shear-wave elastography of breast masses was not significantly better than that of conventional US alone. We have also shown that elastography was useless in the diagnosis of axillary nodal metastases from breast cancer.

Even if the technology of elastography worked flawlessly, the huge overlap in firmness between benign and malignant lesions gives this technology no practical place in the differential diagnosis of solid breast masses. Even the newest techniques of quantification of the elastic modulus with shear-wave elastography will not overcome this lethal flaw. Thus, relying on elastography to avoid a biopsy would be as dangerous as relying on palpation alone in the case of a palpable mass.

We do not use elastography of the breast at our institution. Breast imagers should focus on using the time-proven effective basic US techniques, be aware of artifacts and pitfalls, and refrain from relying on unproven new technologies that will never avoid an "unnecessary biopsy" but, on the contrary, may very well lead to one.

Dynamic US examination of the breast

In making a differential diagnosis between a solid benign mass and a malignant one, more important than the stiffness of the mass is the observation of the immediate environment of the lesion, i.e., determining whether the mass is smooth and slides over the adjacent tissue planes or infiltrates into and "sticks" to the surrounding rim of tissue. This critical information can be gathered only during special and carefully executed dynamic maneuvers in real time with high-resolution grayscale US. These maneuvers include graded compression in the vertical direction and lateral rocking of the transducer to create a lateral translation of the tissues instead of vertical compression. For example, dynamic maneuvers can demonstrate that a presumed fibroadenoma is in reality a lobule of fat or clear a suspicious area of shadowing that is in fact cast by a prominent Cooper's ligament. The sonographer should always use these maneuvers when an artifact is suspected and when more information is needed about the immediate environment of a mass.

In summary, many breast imagers still do not use all the capabilities of grayscale and PDUS imaging, limiting their use of US to merely guiding percutaneous needle biopsies. Breast imagers should focus on the proper use of the time-proven effective basic imaging techniques and take advantage of the

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fact that sonography is *the only real-time cross sectional imaging modality*.

They should be aware of the possible disastrous effects of some oversold image-processing gimmicks and refrain from turning to new unproven technologies that will never avoid an “unnecessary biopsy” but, on the contrary, may very well lead to one.

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