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The Role of Sonoelastography in Breast Lesions

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There is a large body of published material that supports the use of elastography, both strain and shear wave, for characterization of breast lesions. To a lesser extent, elastography can be used in the detection of breast abnormalities. This article reviews the principles of elastography regarding breast imaging, reviews the techniques to perform both strain and shear wave elastography, and reviews the literature and discusses how elastography can be used to improve the characterization of breast lesions to allow for decrease in the number of short-term follow-up examinations and benign biopsies.
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Introduction

The use of palpation for the detection and characterization of disease states has been employed for thousands of years.[1] The ancient Egyptians were known to use palpation to detect pathology. Many disease states cause a change in the stiffness of tissue, particularly in most malignancies. Elastography is the imaging equivalent to clinical palpation. Unlike manual palpation, ultrasound elastography can semiquantitate or quantitate the degree of stiffness of a mass or a tissue. It can also assess stiffness of deep tissues that may not be accessible for clinical palpation.

Ultrasound elastography has been employed in multiple tissues with varying levels of accuracy in detection and characterization of disease states. Organs where ultrasound elastography may improve assessment of disease states include breast, thyroid, liver, prostate, and tendons.[2-7] For focal lesions, the stiffness of malignant breast lesions is much greater than benign lesions with very little overlap allowing for high sensitivity and specificity in characterization of breast lesions as benign or malignant.[5,8,9]

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Basic Principals

There are 2 types of ultrasound elastography, strain elastography (SE) and shear wave elastography (SWE). These techniques use different methods to determine tissue stiffness and are complementary techniques. Each has its advantages and disadvantages. The choice of which (or both) to use is dependent on the availability as well as which organ and disease being evaluated.[2]

Precompression

When the breast is compressed with the transducer the stiffness of the breast increases.[8] This increase in stiffness is identified on both SE and SWE and *must* be avoided for accurate stiffness values. In general, when performing B-mode ultrasound of the breast some compression is needed to avoid refraction artifacts from Cooper's ligaments. Compressing the breast also helps in bringing deep lesions closer to the optimal focal zone. However, these advantages in B-mode imaging will lead to inaccurate elastography results. The addition of compression while scanning is known as precompression. One method to avoid precompression is to identify an object in the image, and then lift the transducer until that object is as deep as possible in the image and transducer contact is still adequate.[10] Another method is to apply a large amount of coupling gel and have some coupling gel between the transducer and the skin while imaging.

Strain Elastography

SE evaluates how a tissue changes when a force is applied to it.[11] Soft tissues deform more than stiff tissues. By comparing

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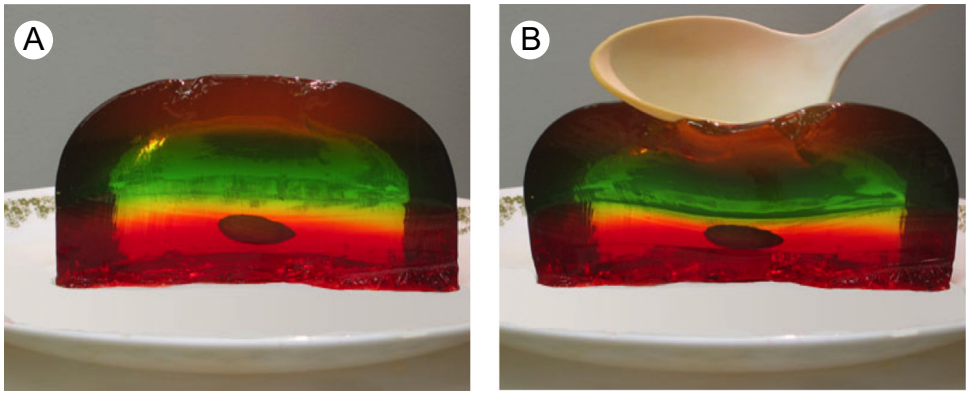

Figure 1 Strain elastography evaluated the frame-to-frame changes in a tissue when a stress is applied. In this simple model of an almond within a bowel of gelatin, when a force is applied with the spoon, the gelatin changes shape while the almond does not change shape. The system, therefore, displays the gelatin as soft and the almond as stiff. The display dynamic range used would be almond black and gelatin that changed the most as white.

the amount of deformation of the various tissues in the field of view (FOV) the tissue types can be mapped based on their relative stiffness (Fig. 1). As the exact force applied is not known, a quantitative measurement of a given tissue stiffness cannot be calculated. The image only displaces the relative stiffness of the tissues in the FOV. The force used to cause the deformation can be from the transducer, patient motion (respiration or cardiac motion), or from an Acoustic Radiation Force Impulse (ARFI) ultrasound pulse. A semiquantitative method of strain is the strain ratio. The strain ratio is the stiffness of the tissue or mass of interest divided by the stiffness of a reference tissue. For breast elastography the reference tissue for strain ratio is fat.[8]

Technique

Each ultrasound system has a "sweet spot" of the degree of compress or release cycle to obtain optimal elastogram. That stress can be from movement of the transducer, from patient motion (respiration or cardiac motion or both), or from an ARFI pulse. If the compress or release is too great, only noise will be obtained on the elastogram, and if not enough compress or release is applied, no elastogram is obtained. Most systems have a numerical scale or diagram that displaces how close the compress or release is to optimal. The technique for each vendor is slightly different and can be learned with practice. It is important to maintain the same imaging plane while performing SE as the technique requires identifying changes in the same location when the force is applied and released. As SE is a *relative* technique, only comparing the stiffness of 1 lesion to another tissue is possible. Therefore, many tissue types should be included in the FOV. For breast, the optimal SE imaging is performed when the FOV includes the lesion, fat, glandular tissue, and the pectoralis muscle.[5] This allows for a relatively stable display dynamic range.

Shear Wave Elastography

SWE is a quantitative technique, that is, a value of the stiffness is obtained. The stiffness value can be displayed as the speed of the shear wave in meters/second (m/s) or making some assumptions as Young's modulus in kilo pascals (kPa). SWE can be performed in a single small region of interest (ROI) (point SWE, p-SWE) or over a larger FOV in which the pixels are color-coded (2D-SWE). The 2D-SWE can be performed as a single shot or in real-time. The use of p-SWE in breast is very limited because there is marked variability of the stiffness with a malignant lesion, and the area of maximum stiffness cannot be identified accurately. Therefore, the remainder of this article will discuss only 2D-SWE. 2D-SWE is performed by applying a strong pulse designed for momentum transfer. This pulse is named ARFI. This pulse generates shear waves that are perpendicular to the ARFI pulse. An analogy is dropping a stone in water; the stone is the ARFI pulse and the ripples are the shear waves (Fig. 2).

Technique

When an area of interest is located, precompression is removed, and the 2D-SWE is turned on. The transducer and patient should remain still during the data acquisition. The image obtained is color-coded with stiff lesions red and soft

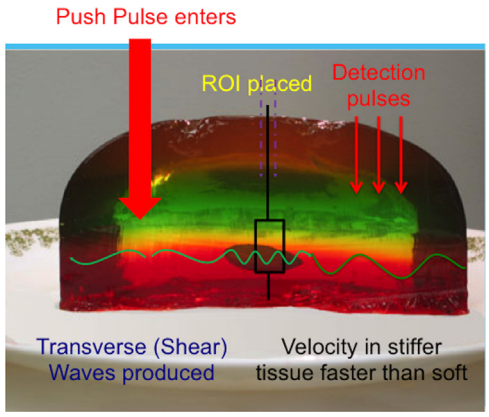

Figure 2 Shear wave elastography applies a push pulse (thick red arrow) that generates shear waves. The shear wave speed varies with the stiffness of the tissue it traverses, fast in stiffer tissue and slow in softer tissue. A region of interest (ROI) is placed at the site of interest. B-mode detection pulses are used to monitor the shear wave progression through tissue and calculate the shear wave speed.