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● *Original Contribution*

PRELIMINARY RESULTS OF ACOUSTIC RADIATION FORCE IMPULSE (ARFI) ULTRASOUND IMAGING OF BREAST LESIONS

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Abstract—The aim of this study was to determine the appearance of breast lesions using acoustic radiation force impulse imaging (ARFI) and to correlate the ARFI values with the pathologic results. The area ratio (AR) and virtual touch tissue quantification (VTQ) values were analyzed in 86 patients (mean age 45.6 years, range 17–78 years) with 92 breast lesions (65 benign, 27 malignant; mean size 25.7 mm). The diagnostic performance of ultrasound (US) alone and US plus ARFI values were compared with respect to sensitivity, specificity and area under the curve (AUC) using a receiver operating characteristic curve analysis. The mean AR of the benign lesions (1.08 ± 0.21) differed from that of the malignant lesions (1.99 ± 0.63; $p < 0.0001$), as did the mean VTQ values (3.25 ± 2.03 m/s vs. 8.22 ± 1.27 m/s; $p < 0.0001$). In conclusion, ARFI provides quantitative elasticity measurements, which may complement B-mode US and potentially improve the characterization of breast lesions. (E-mail: bccjw@sohu.com)

Key Words: **Breast lesions, Acoustic radiation force impulse, ARFI Imaging, Elastography, ultrasound.**

INTRODUCTION AND LITERATURE

In general, benign lesions in the breast tend to be harder than normal breast tissue but softer than cancer (Sewell 1995). This general character forms the basis for some of the examinations that are currently being used in the clinical assessment of breast abnormalities, such as palpation and elastography. Exceptions can occur, but soft malignant lesions, including medullary, mucinous, papillary and some necrotic infiltrating ductal carcinomas, are uncommon (Tavassoli et al. 2003). On the other hand, some benign lesions, such as hyalinized fibroadenomas and fat necrosis, can be hard at palpation. Conventional elastography can be used to estimate breast tissue elasticity (Itoh et al. 2006; Scaperrotta et al. 2008; Burnside et al. 2007; Cho et al. 2008) but there are certain disadvantages with freehand compression: the elasticity map obtained is highly dependent on the compressibility limits under stress of the organ and on the extent of the tissue compression applied. The diagnosis of breast lesions with ultrasonic elastography using a 5-point scoring system is relatively subjective (Zhi et al. 2010), as the displayed information relates to local strain estimated at a given location in the tissues, but this depends on the mechanical properties of the surrounding tissues and is not quantitative.

It has been shown that objective quantification of tissue elasticity could now be possible using acoustic radiation force impulse (ARFI) elastometry. With this system, instead of using external compression, commercially available ultrasound (US) scanners are used to generate short-duration acoustic radiation forces that impart small (1–10 μm) localized displacements in the tissue. The response of the tissue to the radiation force is observed using conventional B-mode imaging pulses to track the tissue displacement, which correlates with the local stiffness of the tissue. Two-dimensional (2-D) images of tissue displacement are created by the repetition of this process along multiple image lines (Nightingale et al. 2001, 2002). The generated waves can provide a qualitative response (gray-scale map) by virtual touch tissue imaging (VTI) or a quantitative response (shear wave velocity values, measured in m/s) by virtual touch tissue quantification (VTQ), dependent upon the interactions with the transducer (Zhai et al. 2008; Palmeri et al. 2008).

ARFI has been evaluated in various tissues using both the grey-scale map and the shear wave speed (Friedrich-Rust et al. 2009; Fahey et al. 2008; Cho et al.

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2010). The purpose of this study was to determine the appearance of breast lesions by ARFI and to assess the correlation between ARFI values (consist of VTI and VTQ values) of lesion stiffness and the pathological results, which were used as the reference standard.

MATERIALS AND METHODS

Patients

The study was approved by the ethics committee of our hospital and all patients gave informed consent. The authors were responsible for all data collection and analysis and for preparation of the information submitted for publication. ARFI was performed following conventional B-mode US in 91 consecutive women who underwent evaluation of breast lesions at our center between September 12, 2010 and December 29, 2010. Five patients were excluded from the study group because of lack of pathologic results. The final study group therefore consisted of 86 patients (mean age 45.6 years, range 17–78 years), who had 92 breast lesions (mean size 25.7 ± 1.8 mm, range 7–46 mm).

Imaging techniques

Two experienced sonographers independently performed US examinations of all the breast lesions. Conventional US was performed using an ACUSON S2000™ US unit (Siemens Medical Solutions, Mountain View, CA, USA) with a linear probe (9L4). Conventional ultrasound scanning was performed on the patients in the supine position with both breasts exposed fully or lateral decubitus position if the lesions were on the lateral of the breast. Both breasts were scanned directly and compared with each other. The ultrasound characteristics and the size of lesions were obtained. The lesion was described using Breast Imaging Reporting and Data System (BI-RADS) lexicon (ACR 2004) sonographic descriptors of mass shape (oval, round, irregular), mass margin (circumscribed, microlobulated, indistinct, angular, speculated), mass orientation (parallel, not parallel), posterior acoustic features (enhancement, no posterior acoustic features, shadowing, combined pattern), lesion boundary (abrupt interface, echogenic halo) and echo pattern (hyperechoic, isoehoic, hypoechoic, complex, anechoic). Lesions were assigned to one of five categories according to the BI-RADS criteria by means of consensus by the two experienced sonographers after they performed independent scans. Table 1 lists the number of each BI-RADS category for breast lesions.

ARFI sequences were performed by the same machine (Siemens Medical Solutions) and the same transducer after conventional B-mode US. VTI was performed in the "VTI" mode in the following manner. The target lesion was displayed in B-mode and then the region-of-interest (ROI) was placed around the lesion. Special care was taken to ensure that sufficient surrounding breast tissue was included in the ROI. To obtain appropriate images, the probe was applied with light pressure to make complete contact with the breast but to let the patient in breath-hold. The VTI button was then pressed and the VTI image was produced on the right of the corresponding B-mode scan. The machine contoured the target lesion in both VTI and B-mode images. The lesion in the VTI image was selected as A1, the corresponding lesion in the B-mode scan as A2 and the area ratio (AR) A1/A2 was obtained.

Table 1. The BI-RADS categories for US (score 1)

Categories	*n* (92)
Category 2	9*
Category 3	22 + 7†
Category 4	34
Category 5	20

BI-RADS = Breast Imaging Reporting and Data System; US = ultrasound.

* The nine lesions, excluded from the statistical analysis, consist of two prosthetic implants and seven cysts.

† Seven lesions were complicated cysts that were excluded from the statistical analysis.

VTQ, performed in the "VTQ" mode, tracks a shear wave within the ROI (size 5 mm × 5 mm) that travels perpendicular to the transmitted longitudinal push pulse. Analysis of time to peak is converted into a numerical value of the shear wave speed (m/s) obtained over the ROI (Nightingale et al.2003). The limits for measurement of the VTQ values (shear wave speed) for this machine were 0–9 m/s. Values outside these limits were displayed as "X.XX m/s". That is to say, both the hard tissue and the fluid were shown as "X.XX m/s". Then, we estimated the quantitative value through the VTI image. The stiffer a tissue, the darker the VTI image. The result was recorded as 0 when the VTI image appeared bright, 9 when the VTI image appeared dark. VTQ values were obtained in breath-hold from each lesion with at least 10 values for quantification. The arithmetic mean of these 10 measurements for each location was used for statistical analysis. The ROI was placed in the breast lesion and the whole ROI was covered by the tumor.

Table 2. Histologic diagnoses of the examined benign and malignant breast lesions.

Benign lesions (*n* = 65)		Malignant lesions (*n* = 27)	
Histopathologic diagnosis	*n*	Histopathologic diagnosis	*n*
Fibroadenoma	37	Invasive ductal carcinoma	24
Fibrocystic mastopathy	6	Papillocarcinoma	1
Papilloma	6	Invasive lobular carcinoma	1
Prosthetic implants*	2	Paget's disease	1
Cystic lesions*	14		

* Sixteen lesions were excluded from the statistical analysis.