Ultrasound in Med. & Biol., Vol. ■, No. ■, pp. 1–6, 2016

0301-5629/$ - see front matter

http://dx.doi.org/10.1016/j.ultrasmedbio.2016.10.004

ELSEVIER

● *Original Contribution*

DIFFERENTIAL DIAGNOSIS OF BREAST CATEGORY 3 AND 4 NODULES THROUGH BI-RADS CLASSIFICATION IN CONJUNCTION WITH SHEAR WAVE ELASTOGRAPHY

MIN WANG,[1] ZHI YANG,[1] CAN LIU, JUNHONG YAN, WENXIAO ZHANG, JIAN SUN, and GUANGHE CUI
Department of Ultrasound, Affiliated Hospital of Binzhou Medical College, Binzhou, China

(*Received* 13 *February* 2016; *revised* 4 *October* 2016; *in final form* 13 *October* 2016)

Abstract—Ultrasound (US) has become one of the important imaging methods for differentiating benign from malignant breast lesions. In 2013, the American College of Radiology published the fifth edition of the Breast Imaging-Reporting and Data System (BI-RADS). BI-RADS is a guide with recommendations for the standardization of breast imaging (US, mammography and magnetic resonance imaging) reports and for the auditing of centers employing such methods. Its objective is to standardize the nomenclature used in the reports. However, current US examinations are neither adequately sensitive nor sufficiently specific enough. The average Young's modulus was measured through shear wave elastography (SWE) to evaluate the diagnostic value of the BI-RADS classification in conjunction with SWE in differentiating BI-RADS 3 and 4 nodules. A total of 100 consecutive women with 126 breast lesions, including 65 benign and 61 malignant lesions, were included. The average Young's modulus of breast nodules and peri-nodule tissue (Emean1 and Emean2) was also determined through SWE. A receiver operating characteristic curve was drawn on the basis of pathologic results. The highest cut-off values were C1 and C2. At Emean1 > C1 or Emean2 > C2, BI-RADS 3 was increased to 4a and BI-RADS 4a was increased to 4b. At Emean1 ≤ C1 and Emean2 ≤ C2, BI-RADS 4b was decreased to 4a. Other BI-RADS classifications remained unchanged. BI-RADS 3 and 4a were considered benign. BI-RADS 4b and 4c were malignant. The area under the curve, sensitivity and specificity of the BI-RADS classification in conjunction with SWE were 0.952, 93.4% and 95.4%, respectively. The area under the curve, sensitivity and specificity of the original BI-RADS classification were 0.883, 82.0% and 87.7%, respectively. Differences were statistically significant ($p = 0.028$, Z-test). The diagnostic sensitivity and specificity were increased effectively. As a new method, BI-RADS classification in conjunction with SWE that combines the average Young's modulus yields a high value in terms of the differential diagnosis of breast nodules. (E-mail: zhiting7@sina.com)

Key Words: **BI-RADS 3 and 4, Shear wave elastography, Breast, Nodules, Classification.**

INTRODUCTION

The current method used to distinguish benign from malignant breast lesions seen at imaging is biopsy, which yields a benign result in more than 75% of patients, making it extremely costly (Poplack et al. 2005). In comparison with other methodologies for detecting breast cancer, such as magnetic resonance imaging, mammography and biopsy, ultrasound (US) has a few advantages: it produces real-time images, has high spatial resolution, is non-invasive and is low cost. With the rapid development of technique, US has become one of the best imaging methods for differentiating benign from malignant breast lesions. The Breast Imaging-Reporting and Data System (BI-RADS) was published by committee members of the American College of Radiology after working together under the cooperation of the U.S. National Cancer Institute, the U.S. Centers for Disease Control and Prevention, the U.S. Food and Drug Administration, the American Medical Association, the American College of Surgeons and the College of American Pathologists. The first edition of BI-RADS was published in 1993, while the US section was first added to the fourth edition in 2003. Up until now, a total of five editions have been published, and

Address correspondence to: Guanghe Cui, Department of Ultrasound, Affiliated Hospital of Binzhou Medical College, Binzhou 256603, China.[1]These authors contributed equally to this study and share first authorship. E-mail: zhiting7@sina.com

[1]These authors contributed equally to this study and share first authorship.

the latest edition was published in 2013 (ACR BI-RADS Atlas, 2013). BI-RADS is a guide with recommendations for the standardization of breast imaging (US, mammography and magnetic resonance imaging) reports and for the auditing of centers employing such methods. Its objective is to standardize the nomenclature used in the reports. However, current US examinations are neither adequately sensitive nor sufficiently specific enough (Bruening et al. 2006) and are also operator dependent. Thus, a method to reliably differentiate benign from malignant breast lesions on US images would be valuable.

As a new imaging technology, shear wave elastography (SWE) can be applied to determine the elasticity of tissues qualitatively and quantitatively. The hardness of lesions is also an essential characteristic, which is usually provided by clinical breast examinations. Compared with static elastography, SWE does not need any manual compression. Being a much less operator-dependent technology than other techniques, SWE provides fine intra- and inter-observer reproducibility (Cosgrove et al. 2012; Yoon et al. 2011).

SWE can improve diagnostic efficiencies on the basis of the BI-RADS classification (Cosgrove et al. 2012; Evans et al. 2010; Ophir et al. 1991). Many scholars have studied breast lesions with SWE, but studies have mostly focused on the stiffest portion with a 2-mm region of interest (Berg et al. 2012; Tozaki and Fukuma 2011) or a suitable region of interest (Klotz et al. 2014; Wang et al. 2013) by determining the optimum cut-off values between benign and malignant lesions and by applying this value to diagnose breast nodules differentially. Evans et al. (2010) found that some malignant breast lesions are characterized by typical peri-tumoral stiffness and had a localized colored area at the margin of lesions, which is a sign of malignancy (Tozaki and Fukuma 2011). Jin et al. (2012) reported that the area ratio (virtual touch tissue imaging to B-mode lesion areas) of benign breast lesions was significantly lower than that of malignant lesions, and the optimum cut-off value obtained through acoustic radiation force impulse elastography was 1.37. In our study, two Q-Boxes, namely, Q-Box1 and Q-Box2, were innovatively used to determine the diagnostic value of SWE. The area of Q-Box2 was 1.37 times of that of Q-Box1. This research aimed to evaluate the diagnostic value of BI-RADS classification combined with the average Young's modulus of breast nodules and peri-nodule tissue.

According to the latest edition published in 2013, BI-RADS 3 is probably benign, with a malignant rate of $\leq 2\%$; BI-RADS 4a is low suspicion, with a malignant rate of 2%–10%; BI-RADS 4b is intermediate suspicion, with a malignant rate of 10%–50%; and BI-RADS 4c is moderate suspicion, with a malignant rate of 50%–95%. This study included BI-RADS 3 and 4 lesions to investigate whether BI-RADS classification in conjunction with SWE can be applied to diagnose breast nodules differentially and accurately.

METHODS

Informed written consent was provided by all patients. This study was performed in accordance with the ethics guidelines of the relevant Chinese laws and was approved by the institutional review board of the Affiliated Hospital of Binzhou Medical College, Binzhou, Shandong Province, China.

Participants

We conducted a retrospective study on a series of 100 female patients aged 26–73 y (mean, 45.9 ± 13.5 y) diagnosed in the Affiliated Hospital of Binzhou Medical College from October 2013 to January 2014. A total of 126 breast lesions of the 100 patients were classified as BI-RADS 3 or 4 on the basis of conventional US and then analyzed with SWE.

BI-RADS 3 lesions were biopsied because of patients' requests or suspicious criteria assessed by other examinations, such as magnetic resonance imaging and mammography. Non-biopsied BI-RADS 3 lesions were regarded as benign because of the absence of morphologic changes or their stability for at least 2 y (Klotz et al. 2014).

Data collection

SWE was performed by using a SWE ultrasound system (Supersonic Imagine, Aix-en-Provence, France) with a linear SL 4–15 MHz transducer. The transducer was placed without compressing the lesions. The patients were instructed to hold their breath and wait for at least 3 s to obtain stable images.

Two operators (M and N) with 3–15 y of radiology experience participated in this study. They also had 5 mo of previous experience in the use of SWE before the study. The Q-Box for each lesion was obtained as follows (Fig. 1). The first Q-Box (Q-Box1) covered the lesion or the area of the lesion on gray-scale as much as possible. The area of the second Q-Box (Q-Box2) was 1.37 times of that of Q-Box1. For each lesion, four successive images were obtained. The following parameters were then determined: average Young's modulus of Q-Box1 (Emean1), average Young's modulus of Q-Box2 (Emean3) and average Young's modulus of peri-nodule area (Emean2). Emean2 could be calculated on the basis of Emean1 and Emean3. We record the average Young's modulus of breast nodules and peri-nodule tissue of the four images, and calculated the final average Young's modulus of the four images.