Ultrasound in Med. & Biol., Vol. 35, No. 11, pp. 1794–1802, 2009

0301-5629/09/$–see front matter

doi:10.1016/j.ultrasmedbio.2009.06.1094

● *Original Contribution*

ANALYSIS OF ELASTOGRAPHIC AND B-MODE FEATURES AT SONOELASTOGRAPHY FOR BREAST TUMOR CLASSIFICATION

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(*Received* 12 *January* 2009, *revised* 10 *June* 2009, *in final form* 20 *June* 2009)

Abstract—The purpose of this study was to evaluate the accuracy of neural network analysis of elastographic features at sonoelastography for the classification of biopsy-proved benign and malignant breast tumors. Sonoelastography of 181 solid breast masses (113 benign and 68 malignant tumors) was performed for 181 patients (mean age, 47 years; range, 24–75 years). After the manual segmentation of the tumors, five elastographic features (strain difference, strain ratio, mean, median and mode) and six B-mode features (orientation, undulation, angularity, average gradient, gradient variance and intensity variance) were computed. A neural network was used to classify tumors by the use of these features. The Student's *t* test and receiver operating characteristic (ROC) curve analysis were used for statistical analysis. Area under ROC curve (*Az*) values of the three elastographic features–mean (0.87), median (0.86) and mode (0.83)–were significantly higher than the *Az* values for the six B-mode features (0.54–0.69) ($p < 0.01$). Accuracy, sensitivity, specificity and *Az* of the neural network for the classification of solid breast tumors were 86.2% (156/181), 83.8% (57/68), 87.6% (99/113) and 0.84 for the elastographic features, respectively, and 82.3% (149/181), 70.6% (48/68), 89.4% (101/113) and 0.78 for the B-mode features, respectively, and 90.6% (164/181), 95.6% (65/68), 87.6% (99/113) and 0.92 for the combination of the elastographic and B-mode features, respectively. We conclude that sonoelastographic images and neural network analysis of features has the potential to increase the accuracy of the use of ultrasound for the classification of benign and malignant breast tumors. (E-mail: rfchang@csie.ntu.edu.tw) © 2009 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Breast tumor, Elastography, B-mode ultrasound, BI-RADS, Neural network.**

INTRODUCTION

Elastography is a noninvasive imaging method developed to evaluate the stiffness of soft tissues (Hall et al. 2003; Ophir et al. 1991). With the use of sonoelastography, the difference in hardness between normal and diseased tissue of the breast can be estimated by measuring the tissue strain induced by probe compression. Several clinical studies have reported that sonoelastography has the potential to differentiate between benign and malignant breast masses (Booi et al. 2008; Garra et al. 1997; Regner et al. 2006). The measured transverse diameters of benign tumors on elastographic images were almost always the same as or smaller than the diameters of the tumors as determined on B-mode images, whereas the diameters of malignant tumors on elastographic images were invariably larger than those on B-mode images (Garra et al. 1997; Hall et al. 2003). This finding results from benign tumors generally having smooth borders and that the benign tumors are loosely bound to the surrounding tissues, whereas malignant tumors are usually characterized by firm desmoplastic reactions with the surrounding tissue.

In current commercial sonoelastography units including the equipment used in this study, the strain data are converted into a color scale images and that are superimposed on B-mode images to recognize easily the relationship between the strain and lesion on the

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B-mode images. Some equipment allows pure strain images to be visualized with data, which is separate from the B-mode data unlike the images used in our study (Tanter et al. 2008).

For the sonoelastographic images, lesion brightness and uniformity as well as the lesion size ratio can help discriminate benign from malignant solid masses (Cho et al. 2008; Itoh et al. 2006; Scaperrotta et al. 2008). Semiquantitative measurement of strain using sonoelastographic images or computer-aided analysis of strain features with continuous B-mode images obtained with probe compression have also been reported (Moon et al. 2005; Zhi et al. 2008). To the best of our knowledge, however, neural network analysis of strain features based on the use of elastographic images has not been used for the classification of benign and malignant breast tumors. Computer-aided analysis of B-mode images of breast lesions has shown the potential to improve the diagnostic accuracy of radiologists to distinguish between malignant and benign breast lesions and to recommend cases for a biopsy (Horsch et al. 2004; Joo et al. 2004; Sahiner et al. 2007).

The purpose of this study was to evaluate the accuracy of neural network analysis of elastographic features at sonoelastography for the classifications of biopsy-proven (as a reference standard) benign and malignant breast tumors.

MATERIAL AND METHODS

Lesions and reference standard

This study was approved by the local ethics committee and informed consent was obtained from all of the included patients. The data used in this study were collected between May 2006 and April 2007 and consisted of 181 biopsy-proved breast tumors (113 benign and 68 malignant) from 181 consecutive women (mean age, 47 years; range, 24–75 years). The malignant lesions were infiltrating ductal carcinoma in 59 cases, infiltrating lobular carcinoma in four cases and ductal carcinoma in situ (DCIS) in five cases. The benign lesions were fibrocystic changes (including ductal hyperplasia, sclerosing adenosis and fibroadenomatous change) in 53 cases, five papillomas, one radial scar and 54 fibroadenomas.

All lesions, except for three fibroadenomas were nonpalpable and were seen as solid breast masses on conventional ultrasound (US). The lesions had been initially classified by attending radiologists as Breast Imaging Reporting and Data System (BI-RADS) (American College of Radiology 2003) category 3– probably benign lesions in 29 cases, category 4–suspicious lesions in 120 cases and category 5–highly suspicious lesions in 32 cases. The mass size as determined on US images was 4–9 mm for 61 lesions, 10–19 mm for 93 lesions and 20–29 mm for 27 lesions. All masses underwent a percutaneous 14-gauge core needle biopsy after sonoelastography and surgery was performed in all 68 lesions with malignant findings within 2 weeks of the US examinations. The histologic diameters of the lesions were 4–30 mm (mean, 12.5 mm) for invasive cancer and 4–36 mm (mean, 14.9 mm) for DCIS. Mammographic and sonographic follow-up was performed in 80% of benign lesions and the mean duration of follow-up was 18.2 months.

Image data acquisition

Sonoelastography and conventional US were performed using a EUB-8500 scanner (Hitachi Medical, Tokyo, Japan) with a 14–6 MHz linear transducer by one of four radiologists with 1–10 years of experience of performing breast US and with knowledge of the clinical and mammographic findings. The scanning protocol included transverse and longitudinal real-time imaging of the target masses with conventional US. For sonoelastography, a region-of-interest box was set to include from the subcutaneous fat layer to the superficial portion of the pectoralis muscle layer and was set to focus on the target lesion. The target lesion was vertically compressed by the transducer with the use of very light pressure. We avoided using higher levels of pressure, which manifest nonlinear properties of tissue elasticity; in such circumstances, the association between pressure and strain is no longer proportional (Itoh et al. 2006).

During the performance of sonoelastography, both elastographic and B-mode images were presented at the same time on a monitor, with the elastographic images on the left and the B-mode image on the right (Figs. 1, 2 and 3). The elastographic images were displayed with the use of 256 color mapping for each pixel according to the degree of strain using a scale from red (highest strain; softest), green (average strain; intermediate) to blue (no strain; hardest). The pressure and speed of compression were adjusted to depict the subcutaneous fat and parenchymal layer as mixed red and green and the muscle layer as blue. Two or three sonoelastographic images were captured per case and the images were sent to a picture archiving and communications system (PACS) and were saved as bitmap files on a hard disc.

Manual segmentation

The radiologist who performed the real-time imaging and an expert radiologist with 15 years experience in the practice of breast US selected representative images of solid masses obtained by the use of sonoelastography in consensus and drew a region-of-interest (ROI) manually on the B-mode images to indicate the tumor contours. The images showing the subcutaneous fat and parenchymal layer as mixed red and green and the muscle layer as blue were selected. Then, the ROI was superimposed on