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● *Original Contribution*

BREAST TUMOR CLASSIFICATION USING FUZZY CLUSTERING FOR BREAST ELASTOGRAPHY

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Abstract—Elastography is a new ultrasound imaging technique to provide the information about relative tissue stiffness. The elasticity information provided by this dynamic imaging method has proven to be helpful in distinguishing benign and malignant breast tumors. In previous studies for computer-aided diagnosis (CAD), the tumor contour was manually segmented and each pixel in the elastogram was classified into hard or soft tissue using the simple thresholding technique. In this paper, the tumor contour was automatically segmented by the level set method to provide more objective and reliable tumor contour for CAD. Moreover, the elasticity of each pixel inside each tumor was classified by the fuzzy c-means clustering technique to obtain a more precise diagnostic result. The test elastography database included 66 benign and 31 malignant biopsy-proven tumors. In the experiments, the accuracy, sensitivity, specificity and the area index Az under the receiver operating characteristic curve for the classification of solid breast masses were 83.5% (81/97), 83.9% (26/31), 83.3% (55/66) and 0.902 for the fuzzy c-means clustering method, respectively, and 59.8% (58/97), 96.8% (30/31), 42.4% (28/66) and 0.818 for the conventional thresholding method, respectively. The differences of accuracy, specificity and Az value were statistically significant ($p < 0.05$). We conclude that the proposed method has the potential to provide a CAD tool to help physicians to more reliably and objectively diagnose breast tumors using elastography. (E-mail: huangcs@ntu.edu.tw; rfchang@csie.ntu.edu.tw) © 2011 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Elastography, Breast tumor, Fuzzy c-means clustering, Stiffness degree, CAD.**

INTRODUCTION

Elastography is a newly developed dynamic technique that uses ultrasound (US) to provide an estimation of tissue stiffness (Ophir et al. 1991; Hall et al. 2003) by measuring the degree of deformation under an external force. It does not only display the conventional B-mode images but also the strain images that represent the relative stiffness of breast lesions compared with that of surrounding tissue in the form of brightness. The US tissue elasticity had become a weighty studying issue in the last 20 years (Gao et al. 1996; Zhu et al. 2008) and has been used largely in clinical tumor studies such as prostate (Curiel et al. 2005; Miyanaga et al. 2006), thyroid (Lyshchik et al. 2005) and breast (Garra et al. 1997; Itoh et al. 2006). Some clinical studies reported that elastography is used to differentiate benign from malignant breast lesions (Garra et al. 1997; Regner et al. 2006; Booi et al. 2008; Cho et al. 2008) based on evaluating the difference in tissue strain between normal and diseased tissue. The classification of elasticity images is, however, dependent on the examiner and significant interobserver variability, and has been found in the reader studies (Regner et al. 2006; Burnside et al. 2007).

During the elastography scanning process, harder regions such as malignant masses deform less readily than their surrounding tissues, whereas softer regions such as benign masses deform more readily than their surrounding tissues (Garra et al. 1997; Doyley et al. 2001; Liu et al. 2003; Tohno and Ueno 2008). Therefore, the evaluated diameters of benign tumors on B-mode images were almost larger than or the same as those estimated on elastographic images, whereas the evaluated diameters of malignant tumors on B-mode

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images were always smaller than those estimated on elastographic images (Garra et al. 1997; Hall et al. 2003). Moreover, malignant masses are normally depicted as darker regions on strain US images with high contrast to background, whereas benign lesions are depicted as brighter regions with lower contrast to background during distortion (Hiltawsky et al. 2001; Hall et al. 2003; Athanasiou et al. 2009). Because the desmoplastic reaction, which evokes a fibrosis response by invading healthy tissue, is often associated with malignant carcinomas and their nearby tissues, our study exploited the hypothesis that there are inherent differences in firmness between benign and malignant breast masses (Krouskop et al. 1998; Wellman et al. 2001; Cho et al. 2010). The lesion size between B-mode and elastographic images and the brightness of masses on elastographic image dissimilarities between B-mode and strain images could be taken as features to distinguish benign from malignant lesions. Itoh et al. (2006) classified US elastrograms into five categories on the basis of lesion brigtness and uniformity as well as lesion size ratio and showed 88.3% (98/111) accuracy, 86.5% (45/52) sensitivity and 89.8% (53/59) specificity for the classification of benign and malignant tumors, with the best sensitivity at 86.5% and specificity at 89.8%.

Moon et al. (2009) developed a computer-aided diagnosis (CAD) method for extracting elastographic and B-mode features from elastography. The extracted features were fed to a neural network for tumor classification, *i.e.*, separating benign from malignant lesions, and accuracy, sensitivity and specificity of the neural network for the classification of solid breast tumors were 86.2% (156/181), 83.8% (57/68) and 87.6% (99/113), respectively. However, they did not accomplish the automatic segmentation technique; therefore, the tumor contour in each represented B-mode image needs to be drawn by the experienced radiologist.

In this paper, to avoid manually delineating the tumor contour, we will adopt an automatic tumor segmentation technique based on the level set method (Sethian 1999). Moreover, this study will further improve the precision of breast tumor diagnosis using the fuzzy c-means (FCM) clustering (Bezdek 1981) rather than taking a fixed threshold as the diagnosing principle. Based on the automatic segmentation and advanced clustering, the proposed system will be an effective tool to help physicians more reliably and objectively diagnose breast tumors using the elastography.

MATERIALS AND METHOD

Lesions

Informed consent was obtained from all involved patients and was ratified by the local ethics committee. The US images used in this research were obtained between August 2008 and November 2008 and contained 97 breast tumors (66 benign and 31 malignant) from 79 consecutive women (mean age, 46.5 y; range 28 to 78). The malignant lesions were invasive in 23 cases and ductal carcinoma *in situ* (DCIS) in eight cases. The benign lesions were fibrocystic changes (including ductal hyperplasia, sclerosing adenosis and fibroadenomatous change) in 44 cases, 2 atypical ductal hyperplasia, 3 papillomas and 17 fibroadenomas.

All lesions were seen as solid breast masses on conventional US. They were classified by the radiologist with 15 years of experience in breast imaging as American College of Radiology Breast Imaging Reporting and Data System (American College of Radiology 2003) category 3—probable benign lesions in 17 cases; category 4—suspicious abnormal lesions in 56 cases; category 5—highly suggestive malignant lesions in 17 cases; and category 6—histologically proven malignant lesions in seven cases. Mass size at US was 3–9 mm in 30 lesions, 10–19 mm in 35 lesions, 20–29 mm in 18 lesions, 30–39 mm in 5 lesions, 40–49 mm in 7 lesions and 50–52 mm in 2 lesions. All masses underwent percutaneous 14-g core needle biopsy, and surgery was performed in all 31 lesions, with malignant findings and five high-risk lesions (2 atypical ductal hyperplasia, 3 papillomas) within two weeks of US examination. The sizes of lesions based on B-mode US were 3–40 mm (mean, 13 mm) for fibrocystic changes, 7–14 mm (mean, 10.3 mm) for papillomas, 7–25 mm (mean, 14.9 mm) for fibroadenomas, 9–30 mm (mean, 19.5 mm) for atypical ductal hyperplasia, 6–49 mm (mean, 22.2 mm) for invasive cancer and 6–52 mm (mean, 25.4 mm) for DCIS.

Image data acquisition

The conventional and grayscale elastography US were obtained using Siemens ACUSON S2000 Ultrasound System (Siemens Medical Solution, Malvern, PA, USA) with the 14L5 transducer, which is a 5–14-MHz linear transducer, by a radiologist who has sufficient clinical knowledge about mammographic findings and has 15 years' experience performing breast US. The scanning protocol in this research included both transversal and longitudinal real-time imaging of target lesions with conventional US. In the grayscale elasticity images, the boundary of region of interest (ROI) was set to include tissues from the subcutaneous fat layer down to the superficial portion of pectoralis muscle layer to make the target lesions focused in the ROI window. The target mass was perpendicularly compressed with tiny force by the transducer. Higher levels of pressure that manifest nonlinear properties of tissue elasticity were avoided to use in each scanning process because of the nonproportional

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