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Computer-assisted assessment of ultrasound real-time elastography: Initial experience in 145 breast lesions

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ABSTRACT

Purpose: To develop and evaluate a computer-assisted method of quantifying five-point elasticity scoring system based on ultrasound real-time elastography (RTE), for classifying benign and malignant breast lesions, with pathologic results as the reference standard.
Materials and methods: Conventional ultrasonography (US) and RTE images of 145 breast lesions (67 malignant, 78 benign) were performed in this study. Each lesion was automatically contoured on the B-mode image by the level set method and mapped on the RTE image. The relative elasticity value of each pixel was reconstructed and classified into hard or soft by the fuzzy c-means clustering method. According to the hardness degree inside lesion and its surrounding tissue, the elasticity score of the RTE image was computed in an automatic way. Visual assessments of the radiologists were used for comparing the diagnostic performance. Histopathologic examination was used as the reference standard. The Student's *t* test and receiver operating characteristic (ROC) curve analysis were performed for statistical analysis.
Results: Considering score 4 or higher as test positive for malignancy, the diagnostic accuracy, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were 93.8% (136/145), 92.5% (62/67), 94.9% (74/78), 93.9% (62/66), and 93.7% (74/79) for the computer-assisted scheme, and 89.7% (130/145), 85.1% (57/67), 93.6% (73/78), 92.0% (57/62), and 88.0% (73/83) for manual assessment. Area under ROC curve (A_z value) for the proposed method was higher than the A_z value for visual assessment (0.96 vs. 0.93).
Conclusion: Computer-assisted quantification of classical five-point scoring system can significantly eliminate the interobserver variability and thereby improve the diagnostic confidence of classifying the breast lesions to avoid unnecessary biopsy.

1. Introduction

Ultrasound real-time elastography (RTE) has recently been explored to evaluate the relative elasticity distribution between a lesion and the surrounding normal tissue and has become a valuable tool for breast lesion characterization [1,2]. Malignant lesions are mostly shown to be harder and produce areas on RTE images larger than the greyscale abnormality on corresponding B-mode images, whereas benign lesions tend to appear similar or slightly smaller on RTE images than on the B-mode images [3]. This property serves as the basis for RTE in classifying benign and malignant breast lesions. Several clinical studies have been reported in the literature [4–7] and some elasticity features, such as strain ratio [8], strain difference [9], softness degree [10], hard area ratio [11] and length ratio [12] have proven to be useful in clinical diagnosis. One of these methods termed five-point scale visual scoring system and first proposed by Itoh et al. [13], according to the degree and distribution of strain induced by light compression, is the most widely long-established and recognized method with RTE images and it show satisfactory results in differentiating benign and malignant lesions of breast, pancreas and thyroid [13–16]. However, the elasticity scores are generally assigned by the examiners and are not yet automated, resulting in significant interobserver variability [16,5]. Quantitative assessment of RTE images by computer has the potential to improve the diagnostic accuracy in order to avoid unnecessary biopsy.

The purpose of this study was to propose a computer-assisted method for quantifying five-point scale scoring system and apply it to classifying benign and malignant breast lesions. To evaluate

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color RTE images automatically and objectively, the level set method, the fuzzy c-means clustering (FCM) method and the quantitative five-point scale scoring algorithm were respectively used for breast lesion segmentation, hard area abstraction and elasticity score quantification. The proposed method was validated by correlating the results of quantitative analysis of RTE images with the diagnosis assessed by the radiologists and histopathologic examination.

2. Materials and methods

2.1. Patients and breast lesions

This study was approved by the Local Ethics Committee, and informed consent was obtained from all of the included patients. The study group consisted of 145 breast lesions (78 benign, 67 malignant) from 104 consecutive women patients (mean age, 42 years; age range, 16–78 years). The benign lesions sizes determined on B-mode images ranged from 3.2 to 112.4 mm (mean size, 17.8 mm), while the malignancies sizes ranged from 4.1 to 43.2 mm (mean size, 23.4 mm). Among benign lesions, there were 49 cases of fibroadenoma, 2 cases of intraductal papilloma, 1 case of cystosarcoma phylloides and 26 cases of fibrocystic change; among malignant lesions, there are 54 cases of invasive ductal carcinoma, 4 cases of mucinous carcinoma, 4 cases of ductal carcinoma in situ, 1 case of invasive papillary carcinoma, 2 cases severe of atypical hyperplasia and 2 cases non-hodgkin's malignant lymphoma.

2.2. Image acquisition

Both the RTE and B-mode US images were performed using the HITACHI HI VISION Preirus system (Hitachi Medical System, Tokyo, Japan) equipped with a 5–13 MHz linear array probe. All the examinations were conducted by one of two radiologists who had 4–10 years of breast US experience and at least 5 month's special training in acquiring RTE images on breast lesions. For RTE images, a region-of-interest (ROI) box was set centered on the target lesion and the surrounding area, including subcutaneous fat, breast tissue and the bottom or poster part pectoral muscle. Two or three sonoelastographic images were captured per case and all these images were saved as DICOM files on a hard disk.

2.3. Manual assessments of elasticity score

The RTE images were displayed with the use of 256-color mapping for each pixel according to the strain values. Each breast lesion was initially assigned an elasticity score on a five-point scale by two skilled radiologists who had more than 2 years' experience in breast elastography examinations and were blinded to the pathologic results. Visual scoring assessments [13] (score 1, the entire lesion was evenly shaded in green; score 2, the hypoechoic lesion had a mosaic pattern of green and blue; score 3, the peripheral part of lesion of lesion was green, and the central part was blue; score 4, the entire lesion was blue, but its surrounding area was not included; score 5, both the entire hypoechoic lesion and its surrounding area were blue) were recorded.

2.4. Reference standard

All breast lesions were subjected to core biopsy or fine needle aspiration cytology for histopathologic diagnosis. In these latter cases, histopathologic results were used as reference standard.

2.5. Computer-assisted assessments of elasticity score

This computer-assisted method consists of four modules, namely elasticity data reconstruction, hypoechoic lesion segmentation, hard area abstraction and elasticity score quantification, which are described in detail as below.

Elasticity data reconstruction. The translucent color RTE images are overlaid on greyscale B-mode US images and saved as the red–green–blue (RGB) format, thus a two-steps process is performed for elasticity data reconstruction. First, for Vision Preirus scanner, the left part is a combination of B-mode and color RTE images, while the right part is the original B-mode image (see Fig. 1(a)). The original color elasticity image can be obtained by subtracting the original B-mode image from the combined image, but still in RGB format (see Fig. 1(b)). Second, the strain information

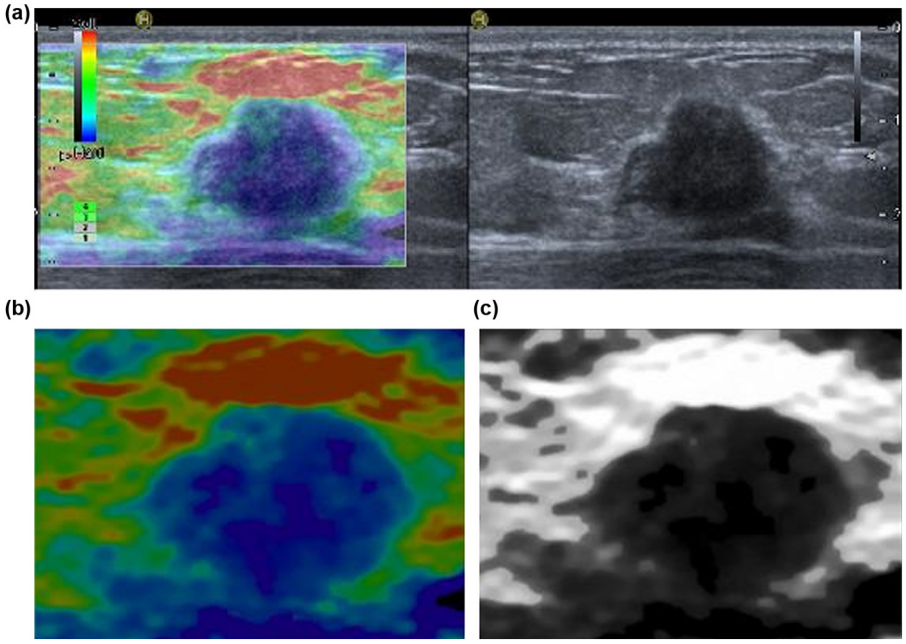

Fig. 1. (a) Original image from Vision Preirus scanner, Left: a combination of B-mode and color RTE images, Right: B-mode US image, (b) color elasticity image (RGB format), and (c) reconstructed elasticity image (grayscale).