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Diagnostic performance of qualitative shear-wave elastography according to different color map opacities for breast masses

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ABSTRACT

Purpose: To compare the diagnostic performance of qualitative shear-wave elastography (SWE) according to three different color map opacities for breast masses

Materials and methods: 101 patients aged 21–77 years with 113 breast masses underwent B-mode US and SWE under three different color map opacities (50%, 19% and 100%) before biopsy or surgery. Following SWE features were reviewed: visual pattern classification (pattern 1–4), color homogeneity (E_{homo}) and six-point color score of maximum elasticity (E_{col}). Combined with B-mode US and SWE, the likelihood of malignancy (LOM) was also scored. The area under the curve (AUC) was obtained by ROC curve analysis to assess the diagnostic performance under each color opacity.

Results: A visual color pattern, E_{homo}, E_{col} and LOM scoring were significantly different between benign and malignant lesions under all color opacities ($P < 0.001$). For 50% opacity, AUCs of visual color pattern, E_{col}, E_{homo} and LOM scoring were 0.902, 0.951, 0.835 and 0.975. But, for each SWE feature, there was no significant difference in the AUC among three different color opacities. For all color opacities, visual color pattern and E_{col} showed significantly higher AUC than E_{homo}. In addition, a combined set of B-mode US and SWE showed significantly higher AUC than SWE alone for color patterns, E_{homo}, but no significant difference was found in E_{col}.

Conclusion: Qualitative SWE was useful to differentiate benign from malignant breast lesion under all color opacities. The difference in color map opacity did not significantly influence diagnostic performance of SWE.

1. Introduction

Shear-wave elastography (SWE) is a recent technique, obtaining elastography images which is based on the combination of a radiation force induced in a tissue by an ultrasonic beam and an ultrafast imaging sequence capable of catching in real time the propagation of the resulting shear waves [1,2]. The displacement induced at the focus generates a shear wave that conveys information linked to the local viscoelastic properties of the tissue, thus enabling a quantitative approach to elasticity values. A very fast (5000 frames/s) ultrasound (US) acquisition sequence is then used to capture the propagation of the shear waves [1,3–5]. Recently, several studies on quantitative SWE of breast lesions have been published, using a conventional linear array probe and so can be included into standard diagnostic breast US examinations [6–9].

SWE with the Aixplorer US system (SuperSonic Imagine, Aix-en-Provence, France) is displayed with a color map and overlaid on top of B-mode with opacity of 50% as default to visualize both B-mode and SWE images. Recently, some studies in which qualitative SWE was used [6,10] have stated that applying pattern classification on color map was useful in making the differential diagnosis between benign and malignant lesions. Although not specifically mentioned, these studies were thought to be performed with color map opacity of 50% as default. Even when color map opacity is adjusted, there is no change of absolute elasticity value obtained by calculating Young's modulus. However, we cannot rule out the possibility of changes in qualitative SWE parameters interpreted subjectively, in line with the change in color map opacity.

The purpose of this study was to evaluate and compare the diagnostic performance of qualitative SWE according to three different color map opacities for breast masses.

2. Materials and methods

This retrospective study was conducted with institutional review board approval and a waiver of patient informed consent.

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2.1. Patients and lesions

From November 2011 to January 2012, one-hundred eleven patients underwent SWE before US-guided core needle biopsy or surgical excision for breast lesions visible on US. Among these patients, ten patients were excluded from this study because SWE images adjusted for color map opacity were not available. A total of 113 breast lesions in 101 women aged 21–77 years (mean, 45.6 ± 8.4 years) were enrolled in this study. Twenty-nine lesions (25.6%) were associated with the following symptoms: palpable mass (n = 27) and nipple discharge (n = 2). The pathology of lesions were confirmed after US-guided core needle biopsy (14-gauge gun biopsy in 62 and 8-or 11-gauge vacuum-assisted biopsy in three) (n = 65) or surgical excision (n = 48). Of the 113 lesions, 30 (26.5%) were malignant and 83 (73.5%) were benign. Malignant lesions included invasive ductal carcinoma (n = 20), ductal carcinoma in situ (n = 6), invasive cribriform carcinoma (n = 1), mucinous carcinoma (n = 1), and invasive micropapillary carcinoma (n = 2). Benign lesions were as follows: fibroadenoma (n = 20), fibrocystic change (n = 21), fibroadenomatous hyperplasia (n = 10), papilloma (n = 6), adenosis (n = 5), stromal fibrosis (n = 8), atypical ductal hyperplasia (n = 1), columnar cell changes (n = 3), usual ductal hyperplasia (n = 3), and others (epidermal cyst (n = 1), benign phyllodes tumor (n = 1), lipoma (n = 1), duct ectasia (n = 1), xanthogranulomatous mastitis (n = 1), hamartoma (n = 1)). Lesion diameter at B-mode US ranged from 3 to 50 mm (mean, 14.2 ± 5.3 mm).

2.2. US examinations

The breast US examinations were performed with the Aixplorer US system (SuperSonic Imagine, Aix-en-Provence, France) equipped with a 15–4-MHz linear-array transducer, by one of four radiologists with 5–10 years of experience in breast US. The investigator knew the results of clinical examination and mammography at the time of the US examination. After obtaining B-mode US, SWE images with color map opacity 50% were obtained for the breast lesions that were scheduled to be biopsied or excised surgically. And then we brought out SWE images on each case, adjusted them from color map opacity 50% to 100% and 19% and saved the images.

2.3. Image evaluation

Each US image was reviewed independently by three radiologists who were blinded to clinical, mammographic, and pathologic findings. A six-step sequential reading was performed by using the six data sets consisting of three session of SWE alone under color map opacities of 50%, 19% and 100% and three session of a combined set of B-mode US and SWE under color map opacities of 50%, 19% and 100% with a 2-week interval between each reading session. The order of cases within each reading session was randomized to reduce bias. Regarding B-mode US image, two representative transverse and longitudinal US images were selected for each lesion.

At SWE alone reading session, a representative opaque SWE color overlay image with the underlying B-mode image (opacity set to 50%, 19%, or 100%) was shown. To collect SWE variables, each reviewer recorded the qualitative maximum elasticity using a six-level visual color scale (E_{col}; black, dark blue, light blue, green, orange and red) and the homogeneity of elasticity within the lesion and surrounding tissue (E_{homo}; very homogeneous, reasonably homogeneous, not homogeneous) [6,10]. Also, SWE color pattern of each lesion was recorded as one of four patterns after the visual evaluation proposed by Tozaki and Fukuma [10] (Fig. 1). When no difference from the color around the lesion was observed at the margin of the lesion or in its interior (coded blue homogeneously), the image was classified as 'no findings' (pattern 1) (Fig. 1a). When a color that differed from the color around the lesion was observed at the margin or in the interior of the lesion,

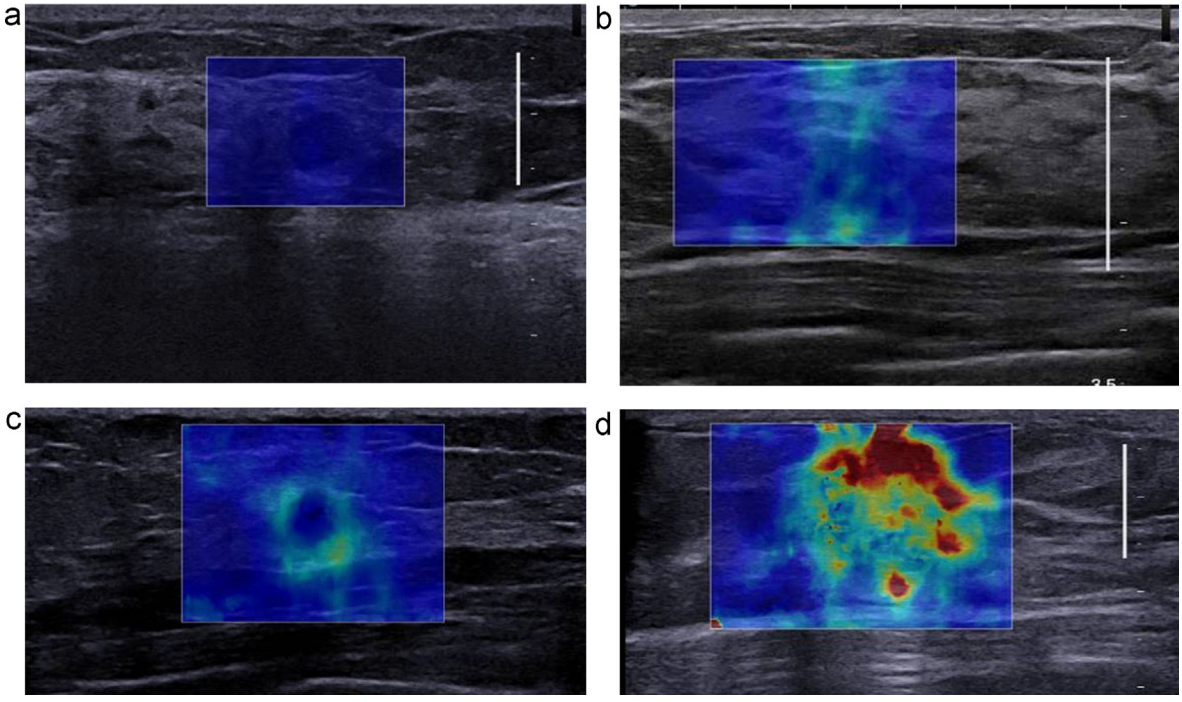

Fig. 1. Four color patterns on SWE. (A) Pattern 1: no difference from the color around the lesion is observed at the margin of the lesion or in its interior. (B) Pattern 2: a color that differs from the color around the lesion is observed at the margin or in the interior of the lesion, but it extends beyond the lesion and continues vertically in cords on the cutaneous side or the thoracic wall side. (C) Pattern 3: a localized colored area is present at the margin of the lesion. (D) Pattern 4: colored areas are present in the interior of the lesion heterogeneously.