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● *Original Contribution*

SEMI-QUANTITATIVE STRAIN RATIO DETERMINED USING DIFFERENT MEASUREMENT METHODS: COMPARISON OF STRAIN RATIO VALUES AND DIAGNOSTIC PERFORMANCE USING ONE- VERSUS TWO-REGION-OF-INTEREST MEASUREMENT

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Abstract—We evaluated the agreement and diagnostic performance of strain ratio values using measurements made with one and two user-defined regions of interest (ROIs) on breast elastography. Two hundred forty-three breast masses of 226 women (mean age: 48.2 y) were included. Ultrasonography (US) and elastography images of the masses were recorded. Strain ratio was measured twice on the same elastography image; strain ratio 1, applying one ROI at the target mass for measurement, and strain ratio 2, applying one ROI at the target mass and another ROI as reference strain. The two strain ratio measurements were in substantial agreement, with an intra-class correlation coefficient of 0.655 (95% confidence interval: 0.577–0.722). Specificity, positive predictive value and accuracy (cutoffs: 2.66 and 2.35) were significantly improved for US combined with the two strain ratio measurements (all *p* values < 0.05). Strain ratios measured using one or two user-defined ROIs were in substantial agreement, both contributing to the improved diagnostic performance of breast US. (E-mail: Ekkim@yuhs.ac)

Key Words: **Breast, Ultrasonography, Elastography, Strain ratio, Region of interest.**

INTRODUCTION

Ultrasonography (US) of the breast is widely used today in breast imaging for lesion detection and characterization. Complementary to the morphologic features of the lesion seen on breast US, US elastography, a non-invasive imaging modality that visualizes the intrinsic stiffness of a breast mass, has recently been applied to the diagnosis of breast masses detected on US (Itoh et al. 2006). The basic principle underlying elastography is that cancer tissues are stiffer than the surrounding normal parenchyma (Garra 2007; Yoon et al. 2011), and by visualizing the tissue stiffness or strain of a mass, we gain additional information that can be used in differential diagnosis of breast masses. Elastography has been reported in many studies to improve the diagnostic performances of gray-scale breast US (Burnside et al. 2007; Cho et al. 2008; Fischer et al. 2012; Itoh et al. 2006; Yoon et al. 2011), and is at present widely accepted as an adjunctive imaging modality that can be considered for better characterization of breast masses detected on breast US (American College of Radiology 2013).

Ultrasound elastography enables visualization of the amount of tissue displacement secondary to the external force applied (Itoh et al. 2006; Yoon et al. 2011), displayed either as (i) a qualitative pattern analysis from the color pattern visualized on the elastography image or (ii) a quantitative elasticity measurement of the breast mass that is automatically calculated by the US machine. Although pattern analysis has been reported to improve the diagnostic performance of gray-scale US, it is highly subjective in terms of both image acquisition and pattern interpretation (Yoon et al. 2011). Strain ratio, a semiquantitative elasticity value that expresses the relative stiffness of a mass compared with the surrounding fat, is used to obtain a more objective elasticity value for strain elastography (Yoon et al. 2016). Strain ratios are commonly obtained by using

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two regions of interest (ROIs) for calculation, one at the target mass and one at the surrounding fat, and is still somewhat subjective compared with recently introduced quantitative elastography techniques such as shear wave elastography and acoustic radiation force impulse (ARFI) because the ROI set for fat measurement may differ among performers, influencing the strain ratio value (Cho et al. 2010; Havre et al. 2011). Recently, strain ratio measurement using one user-defined ROI has been developed and applied to breast imaging (Duda and Kohler 2014; Yoon et al. 2016). As with strain ratios measured using two ROIs, one-ROI strain ratios have been reported to have higher specificity to gray-scale US (Yoon et al. 2016), but no studies have compared the differences in strain values or the diagnostic performance of strain ratios measured using one or two user-defined ROIs when applied to the diagnosis of breast masses.

We evaluated the agreement of strain ratio values between one- and two-ROI measurements, and compared the diagnostic performance of the two strain ratio measurements when applied to the diagnosis of breast masses observed on US.

METHODS

This study had a prospective design and was approved by the institutional review board of Severance Hospital, Seoul, Korea. Informed consent was obtained from all patients for study inclusion.

Patients

From January to May 2016, 243 breast masses in 226 women who were scheduled for breast US examinations, US-guided biopsy or breast surgery were included in this study. Mean age of the 226 women was 48.2 ± 12.7 y (range: 19–83 y). Mean size of the 243 breast masses included was 15.5 ± 9.5 mm (range: 5–47 mm). Of the 243 breast masses, 217 (89.3%) were pathologically diagnosed with one of the following methods: US-guided core needle biopsy (n = 100), US-guided vacuum-assisted biopsy or excision (n = 21) and surgery (n = 96). Twenty-six (10.7%) breast masses were included based on prior benign biopsy results and stability for more than 2 y of follow-up (n = 20) and typical US features such as cysts (n = 6).

US examinations and biopsy

Gray-scale US and elastography images were obtained using a 3- to 12-MHz linear transducer (RS80A with Prestige; Samsung Medison, Seoul, Korea). US examinations were performed by one of two radiologists with 7 and 15 y of experience in breast imaging (J.H.Y. and E.K.K.). After detection of the breast mass for biopsy or surgery on gray-scale US, elastography was performed. US images were analyzed by the radiologists individually based on the final assessments made with the American College of Radiology Breast Imaging Reporting and Data System (ACR BI-RADS) (American College of Radiology 2013). Strain ratio measurements obtained from elastography were recorded. Biopsy, when required, was performed after US and elastography examinations by the same radiologist who had performed breast US.

US elastography and strain ratio measurement

Elastography examinations were performed with a freehand technique, positioning the transducer perpendicular to the skin and applying very light pressure. Elastography images are displayed in a split-screen mode with gray-scale images on the left and corresponding elastography color images on the right. Real-time elastography images were visualized according to a 256-color mapping that represents the amount of strain within the region, ranging from *red* (greatest strain or softest area), to *green* (average strain), to *blue* (no strain or hardest area) (Yoon et al. 2016). Elastography images of adequate image quality (i.e., considered to represent the target breast mass well by the individual radiologist who performed the elastography) examination were selected and stored for strain ratio measurements.

The strain ratio was obtained twice using the same elastography image (Fig. 1a). Strain ratio 1 was measured by applying a single round or oval ROI at the targeted breast mass, in which mean strain of the breast mass (target strain) is defined as the mean strain within the ROI; mean strain within the reference (reference strain) is measured as the mean strain of the fat located at the level of and above the ROI set for target strain measurement, excluding the target strain ROI area (Fig. 1b) (Yoon et al. 2016). Strain ratio 2 was measured by applying two ROI: one drawn along the targeted breast mass (target strain) and one at the subcutaneous fat layer area displaying homogeneously green elasticity (reference strain) (Yoon et al. 2011) (Fig. 1c). Strain ratio was calculated as mean strain within reference (reference strain)/mean strain within lesion (target strain).

Regions of interest used to measure target strain were adjusted to include most of the target mass seen on gray-scale US images. Strain ratio was automatically calculated by the US machine, the elastography image containing the calculated strain ratio was stored and the strain ratio value was recorded for data analysis.

Data and statistical analysis

Histopathologic results from US-guided core needle biopsy, vacuum-assisted excision or surgery were considered the reference standard. The final pathologic