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● *Original Contribution*

SLIP IMAGING: REDUCING AMBIGUITY IN BREAST LESION ASSESSMENT

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Abstract—Ultrasound elasticity imaging (elastography) is gaining popularity as an adjunct to B-mode ultrasound for breast cancer diagnosis. Cancerous masses are usually stiffer than normal tissue, hence, using elasticity imaging should lead to better differentiation between benign and malignant masses than using B-mode alone. Clinicians assess the mobility of masses on palpation; cancers usually being less mobile. We introduce a method to estimate mobility, called slip imaging and combine it with conventional B-mode and elasticity data. In the reported evaluation on 70 women recalled to a breast assessment clinic, images were scored by three breast radiologists independently. Diagnostic accuracy increased from 75.7% with B-mode alone, to 78.1% when including elasticity imaging, to 80.0% when further including slip imaging. Specificity increased (74.6%:75.4%:82.5% respectively), with an apparent trade-off in sensitivity (77.1%:81.3%:77.1%). We conclude that Slip imaging is potentially a useful adjunct to B-mode and elasticity imaging and should undergo further research and development. (E-mail: noble@robots.ox.ac.uk) © **2010 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Breast cancer, Elasticity imaging, Elastography, Breast ultrasound, Computer-aided detection, Tissue imaging.**

INTRODUCTION

Routine mammographic screening of women is widely performed and approximately 4% to 13% will be recalled for further assessment (Smith-Bindman et al. 2005). Ultrasound (US) is used to assess mammographically detected breast abnormalities and is helpful in distinguishing solid lesions from cysts. Although many lesions are recalled from assessment, the small ones can be challenging to characterize. To minimise unnecessary invasive procedures, it is important to keep the number of benign lesions, which have undergone a biopsy low, yet maximise the number of malignant lesions diagnosed.

When a breast mass is examined by manual palpation, two component features are observed – the firmness or stiffness of the mass, and its mobility. Malignant breast masses tend to be harder (more stiff) than benign ones and benign breast masses tend to be more mobile than malignant ones. The relative stiffness of a mass with respect to surrounding tissues can be measured by US elasticity imaging (also called elastography or strain imaging). US elasticity imaging estimates stiffness from the amount of axial deformation (strain) produced by light tissue compression using a transducer. Some studies have suggested that elasticity imaging might increase the diagnostic accuracy of US assessment (Garra et al. 1997; Itoh et al. 2006; Burnside et al. 2007) and reduce the proportion of benign lesions that undergo biopsies (Itoh et al. 2006). However, breast elasticity imaging is still regarded by many as an experimental technique, with several difficulties to be overcome, especially the highly operator dependent precompression and compression (Merritt 2008). In an attempt to reduce this variability, we have developed and used in this study an automated compression device (Kadour and Noble 2009). However, there also remains the issue that some benign lesions, notably fibroadenomas, are also stiffer than normal tissue, which can be problematic for elasticity imaging. This motivated us to develop and evaluate a new technique, which we call slip imaging, for quantifying the degree of mobility of a suspicious mass relative to its surroundings, which we report on in this article.

This article examines the effect on diagnostic accuracy of adding slip imaging to conventional B-mode

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ultrasound and elasticity imaging (we call the combined representation BES in this article). Slip images are created in a manner similar to elasticity imaging, except that the mobility through the deformation is displayed instead of the strain (see the Materials and Methods section for a further discussion on slip imaging). Evaluation on images from 70 women recalled to a breast assessment clinic reported in the Results section shows the value of using the BES representation to differentiate benign from malignant lesions.

MATERIALS AND METHODS

Patients

Participants in the study were recruited prospectively from a breast screening programme assessment clinic. This study was approved by the local ethics committee and informed consent was obtained. All women undergoing US-guided diagnostic needle biopsy were invited to participate in the study, which implicitly means only women with negative B-mode ultrasound findings were excluded. All solid lesions were included in the analysis. Simple cysts larger than 25 mm were excluded as these do not pose diagnostic difficulty.

Seventy women were imaged from September 2005 to October 2006. Some of the women may have had multiple lesions but all had only one suspicious mass (the nonsuspicious masses would have been simple cysts), thus, we had 70 lesions in the study. The mean age was 58.4 years (range 49–76). The women had been recalled to an assessment clinic following routine mammographic screening and had lesions visible on ultrasound.

Table 1 summarizes the pathologic diagnosis of the 70 lesions. Lesions were classified as benign ($n = 38$) or malignant ($n = 32$) according to the results of needle biopsy. Complicated cysts were confirmed by US-guided fine needle aspiration and all solid lesions underwent US-guided 14-gauge core biopsy, following standard clinical practice. Of the 38 benign lesions, 21 were solid and 17 were cystic. Of the 17 cystic lesions, there were no complex cysts and three of the cysts were inspissated (classified by Breast Imaging Recording and Data System [BI-RADS] as complicated). All malignant lesions were subsequently excised surgically. All biopsy and surgical specimens were reported by one of three specialist breast pathologists with 9, 3 and 2 years experience. There were no new findings over the following 36 months.

Table 1. Final pathologic diagnosis of 70 breast lesions

Pathologic diagnosis	No. of lesions
Benign	38
Cyst	17
Fibroadenoma	7
Fibrocystic change	7
Stromal fibrosis	2
Papilloma	1
Fat necrosis	1
Pseudoangiomatous stromal hyperplasia	1
Apocrine adenosis	1
Benign epithelial proliferation	1
Malignant	32
Invasive ductal carcinoma	18
Invasive lobular carcinoma	8
Invasive tubular carcinoma	2
Invasive micropapillary carcinoma	1
Medullary carcinoma	1
Ductal carcinoma *in situ*	1
Carcinoid	1

Equipment

Imaging was performed using the Assisted-Freehand Ultrasound (AFUSON) system (Kadour and Noble 2009). A performance assessment of that device has been previously reported in Kadour and Noble (2009) and readers are referred to that paper for technical details on the system. Briefly, AFUSON is built around a standard commercial ultrasound system (AN2300; Analogic Corporation, Peabody, MA, USA) with a 12 MHz, 30 mm linear array transducer used for routine freehand acquisitions. It uses a transducer attachment that includes a stepper-motor to automatically compress the tissue for elasticity and slip imaging. Device-controlled movement improves elasticity imaging quality and reduces interobserver variability. The probe is mounted in a holder which is schematically shown in Figure 1. The innermost chamber contains the ultrasound probe. Probes vary in shape so expanding foam is used to secure the probe firmly. The chamber rotates within the middle chamber (although rotation is not used in this study). The middle chamber runs on a linear slide from a small gantry located above the two inner chambers. This second chamber translates by a stepper-motor-driven linear actuator mounted on the gantry that delivers the compressions to the tissue. Compression is delivered continuously at a rate of 10 mm/s. In this study, a total compression of 4 mm is made and images are acquired in real-time during decompression to create the elasticity and slip images.

Slip imaging

Slip imaging attempts to quantify the degree of mobility or slip of soft tissue (Kadour 2007; Kadour and Noble 2007). In the current study, slip imaging is defined using the sum-of-squared differences error from a two-dimensional (2-D) block-matching motion estimation algorithm as generically described in Hall et al. (2003). The error estimate from successive image pairs is summed to give an accumulative error, which is taken as the slip (mobility) value. The specific motion estimation algorithm used in this work incorporated multiscale