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● *Original Contribution*

WHOLE-BREAST ULTRASOUND FOR BREAST SCREENING AND ARCHIVING

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Abstract—The incidence of breast cancer is increasing worldwide, reinforcing the importance of breast screening. Conventional hand-held ultrasound (HHUS) for breast screening is efficient and relatively easy to perform; however, it lacks systematic recording and localization. This study investigated an electromagnetic tracking-based whole-breast ultrasound (WBUS) system to facilitate the use of HHUS for breast screening. One-hundred nine breast masses were collected, and the detection of suspicious breast lesions was compared between the WBUS system, HHUS and a commercial automated breast ultrasound (ABUS) system. The positioning error between WBUS and ABUS (1.39 ± 0.68 cm) was significantly smaller than that between HHUS and ABUS (1.62 ± 0.91 cm, $p = 0.014$) and HHUS and WBUS (1.63 ± 0.9 cm, $p = 0.024$). WBUS is a practical clinical tool for breast screening that can be used instead of the often unavailable and costly ABUS. (E-mail: rfchang@csie.ntu.edu.tw) © **2017 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Breast mass, Automated breast ultrasound, Comparative study, Hand-held ultrasound, Computer-aided tracking system, Whole-breast ultrasound.**

INTRODUCTION

Breast cancer is one of the most common cancers and the leading cause of cancer-related deaths in women worldwide, and its incidence is rapidly increasing. In recent decades, mammography has been considered one of the best screening techniques for detection and diagnosis of breast cancer and it has been proven to reduce breast cancer mortality (Feig 1988). However, the reduced sensitivity of mammography screening for dense breasts and women younger than 50 y of age remains a major limitation (Kerlikowske et al. 1996). Hand-held ultrasound (HHUS) is widely available, relatively inexpensive and well tolerated by patients (Mendelson and Tobin 1995). Previous studies have suggested that HHUS is capable of detecting breast masses in dense breasts, as in young women (Kaplan 2001; Leconte et al. 2003; Osako et al. 2007). Furthermore, performing both HHUS and mammography has been reported to provide more accurate screening results, ultimately leading to improved treatment and reduced mortality from breast cancer (Berg et al. 2008; Leconte et al. 2003; Nothacker et al. 2009; Ohuchi et al. 2016; Osako et al. 2007).

Hand-held ultrasound is, however, limited by operator dependency and non-reproducible results. Lesions detected on HHUS were annotated subjectively during examination. It is difficult to localize a 2-D image plane and then reproduce the same image plane at a later point (Lin et al. 2012). Thus, 3-D automated breast ultrasound (ABUS) was developed to overcome these problems (Ikedo et al. 2007). The ABUS system is less operator dependent, as technologists perform ABUS without lesion identification and annotation. After image acquisition and reconstruction by the workstation, a physician can evaluate the stored images any time after the ABUS examination, and the detected lesions would be annotated automatically (Kim et al. 2013; Shin et al. 2011; Tozaki et al. 2010; Wenkel et al. 2008). ABUS is similar to HHUS in terms of sensitivity (95.3% vs. 90.6%) and specificity (80.5% vs. 82.5%) in distinguishing benign from malignant breast lesions (Wang et al. 2012). The sensitivity of using ABUS with mammography in breast tumor detection has been found to be significantly increased, from 50% to 81%, an improvement of 63% in the identified cancer cases (Kelly et al. 2010). ABUS

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has potential in the standardization of whole-breast scanning because it is less operator dependent and reproducible by its systematic recording system (Giuliano and Giuliano 2013; Golatta et al. 2013; Kim et al. 2014).

Despite these advantages, ABUS is relatively new and comparatively more expensive than conventional cancer screening systems, thus restricting its widespread adoption. Hence, 2-D ultrasound imaging remains the most popular scanning tool for breast ultrasound examinations. Recently, a commercial magnetic navigation system (trakSTAR, Ascension, Shelburne, VT, USA) was introduced to track the movement of a sonography probe to coordinate sonography with magnetic resonance imaging and thereby improve the reproducibility of sonographic measurements (Nakano et al. 2012). In this study, the trakSTAR system was used to develop an electromagnetic tracking-based whole-breast ultrasound (WBUS) system for breast screening and data archiving. With the magnetic sensor device fixed to the HHUS transducer, the WBUS system could track the 3-D spatial position of the sensor on the transducer and then transform data on its location into a radial angle to the nipple expressed in clock format, along with the distance to the nipple expressed in centimeters. The tracking images and routes were displayed on a screen for real-time reference and archived for retrospective examinations. Image acquisition and assessment could be performed separately. This study evaluated the feasibility of the clinical application of this WBUS system and compared the reliability of detecting suspicious lesions using HHUS, ABUS and WBUS.

METHODS

One-hundred nine breast masses from 100 patients detected by HHUS, ABUS and WBUS were included in this study; 67 were malignant and 42 were benign. The patients were scheduled for core needle biopsy, excisional biopsy or other surgical interventions at National Taiwan University Hospital between June 2014 and June 2015 (Table 1). Their mean age was 52.47 ± 12.88 y. The institutional review board of our hospital approved this study, and all patients signed informed consent before the examinations (201403056 RINB).

A physician with 3 y of experience in breast imaging reviewed all breast images. Four trained licensed technologists scanned the patients using HHUS, and one trained licensed technologist scanned the patients using WBUS and ABUS. The parameters evaluated by the physician included lesion size, location, and Breast Imaging Reporting and Data System category on HHUS, ABUS and WBUS. The location data of the three examinations were recorded. Distances between any two measurements from the three examinations described above were calculated for further comparisons.

Table 1. Patients' characteristics and histopathologic results

Characteristic	No.	%
Age, mean ± SD	52.47 ± 12.88	
Histopathology		
Malignant	67	61
Benign	42	39
BIRADS		
2	4	4
3	6	6
4a	23	21
4b	13	12
4c	15	14
5	48	44
Lesion size		
<1.0	25	23
1.0–2.0	38	35
2.0–3.0	27	25
>3.0	19	17

SD = standard deviation; BIRADS = Breast Imaging Reporting and Data System.

Conventional hand-held ultrasound

Conventional HHUS examinations were performed with a GE Voluson E6 (GE Healthcare, Milwaukee, WI, USA) equipped with a 3- to 12-MHz linear-array ultrasound probe (11 L-D) by trained licensed technologists. Bilateral whole-breast HHUS examinations were performed in transverse and sagittal overlapping orientations in a supine position, with the woman's arm raised above her head. The technologist documented each detected lesion with an image of its largest horizontal diameter (both horizontal and vertical diameters were recorded) and an image perpendicular to that with its respective diameter. The detected breast lesion was annotated by the physician, with the radial angle to the nipple expressed in clock format and the distance to the nipple expressed in centimeters. The average time for each HHUS examination was approximately 20 min.

Automated breast ultrasound

For ABUS, an ACUSON S2000 Automated Breast Volume Scanner (Siemens Medical Solutions, Mountain View, CA, USA) equipped with a 5- to 15-MHz linear array transducer (14 L5 BV) was used by a trained technologist. The system comprised an automated breast volume scanner module with core components including flexible arms, touch screen monitor and scanner (transducer, scan box and screen membrane for contact). When scanning with the automated system, customized presets were used to optimize the depth, gain, frequency and view. All patients underwent ABUS examinations in a supine position. Depending on breast size, at least three