Ultrasound in Med. & Biol., Vol. ■■, No. ■■, pp. ■■–■■, 2018

0301-5629/$ - see front matter

https://doi.org/10.1016/j.ultrasmedbio.2018.03.001

● *Original Contribution*

PRE-OPERATIVE PLANNING USING REAL-TIME VIRTUAL SONOGRAPHY, AN MRI/ULTRASOUND IMAGE FUSION TECHNIQUE, FOR BREAST-CONSERVING SURGERY IN PATIENTS WITH NON-MASS ENHANCEMENT ON BREAST MRI: A PRELIMINARY STUDY

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(*Received* 8 *September* 2017; *revised* 12 *February* 2018; *in final form* 1 *March* 2018)

Abstract—The purpose of this retrospective study was to evaluate the effect of pre-operative planning using real-time virtual sonography (RVS), a magnetic resonance imaging (MRI)/ultrasound (US) image fusion technique on breast-conserving surgery (BCS) in patients with non-mass enhancement (NME) on breast MRI. Between 2011 and 2015, we enrolled 12 consecutive patients who had lesions with NME that exceeded the US hypo-echoic area, in which it was particularly difficult to evaluate the tumor margin. During pre-operative planning before breast-conserving surgery, RVS was used to delineate the enhancing area on the breast surface after additional supine breast MRI was performed. We analyzed both the surgical margin positivity rate and the re-operation rate. All NME lesions corresponded to the index cancer. In all patients, the diameter of the NME lesion was greater than that of the hypo-echoic lesion. The median diameters of the NME and hypo-echoic lesions were 24 mm (range: 12–39 mm) and 8.0 mm (range: 4.9–18 mm), respectively (p = 0.0002). After RVS-derived skin marking was performed on the surface of the affected breast, lumpectomy and quadrantectomy were conducted in 7 and 5 patients, respectively. The surgical margins were negative in 10 (83%) patients. Two patients with positive margins were found to have ductal carcinoma in situ in 1 duct each, 2.4 and 3.2 mm from the resection margin, respectively. None of the patients required additional resection. Although further prospective studies are required, the findings of our preliminary study suggest that it is very well possible that the use of RVS-derived skin marking during pre-operative planning for BCS in patients with NME would have resulted in surgical outcomes similar to or better than those obtained without the use of such marking. (E-mail: snakano1@aichi-med-u.ac.jp)

Key Words: **Breast cancer, Pre-operative staging, Surgical planning, Margin positivity, Re-operation, Surgical outcome, Supine-position breast magnetic resonance imaging, Breast ultrasound.**

INTRODUCTION

Non-mass enhancement (NME) in breast magnetic resonance imaging (MRI) is defined in the Breast Imaging Reporting and Data System (BI-RADS) lexicon of the American College of Radiology (ACR) as an area of enhancement without an associated space-occupying mass or focus (American College of Radiology 2013). Many cases of ductal carcinoma *in situ* (DCIS) are detected as NME and exhibit segmental or ductal distribution and clumped internal architecture (Liberman et al. 2002; Morakkabati-Spitz et al. 2005). The potential benefits of pre-operative MRI are still controversial, and international guidelines do not recommend MRI for routine pre-operative assessment. However, when breast-conserving surgery (BCS) is considered for NME biopsy-proven malignancy, precise localization of surgical position is required

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Conflicts of Interest: The authors report no conflicts of interest.

to reduce local recurrence and to avoid excessive resection. Although breast ultrasound (US) plays an adjunctive role in the evaluation of MRI findings during pre-operative planning for BCS, NME is less likely than a mass or focus to have a US correlate, and the rate of identification of NME in second-look US has varied among studies (Abe et al. 2010; Hollowell et al. 2015; Newburg et al. 2017; Park et al. 2013; Spick and Baltzer 2014). Furthermore, breast MRI is performed with the patient in the prone position, and because of the breast deformation in these cases, it is difficult to sonographically identify MRI-enhancing lesions without adjacent landmarks that can be identified by both US and MRI.

Real-time virtual sonography (RVS), which can synchronize US and MR images *via* multiplanar reconstruction (MPR) of the same section in real time, was recently introduced in breast imaging. By addition of supine MRI, RVS can be used to conduct the probe to the MRI-enhancing target lesion without the presence of a landmark or any special experience on the part of the US operator (Nakano et al. 2009). We reported that second-look US using RVS improved the sonographic and histopathological detection rates of conventional B-mode-occult MRI-detected lesions (Nakano et al. 2012a; Watanabe et al. 2017). Although several authors have reported the usefulness of RVS in breast imaging (Kang et al. 2017; Nakano et al. 2012b, 2014; Uematsu 2013; Uematsu et al. 2016), few studies have investigated the usefulness of RVS in surgical planning for BCS with NME.

The purpose of this retrospective study was to evaluate the effect of pre-operative planning using RVS on outcomes of BCS for NME biopsy-proven malignancy.

METHODS

Patients and characteristics

This preliminary retrospective study was approved by the institutional review board at our hospital. The need for written informed consent for this evaluation was waived. Between January 2011 and December 2015, 12 consecutive patients (all women, median age: 63 y, range: 48–74 y) with NME that exceeded the hypo-echoic area on US were enrolled. Before surgery, all hypo-echoic areas were determined by biopsy to represent malignancy.

MRI examination

Prone MRI with a 1.5-T imager (Magnetom, Siemens Medical Systems, Erlangen, Germany) was performed with a dedicated double breast coil with the patient's arm raised. We performed 3-D volumetric multiphase image acquisitions with the following parameters: TR/TE, 5/2 ms; flip angle, 10°; field of view, 340 mm; acquisition time, 72 s; and slice thickness, 2.2 mm. A bolus of contrast material (gadodiamide, Omniscan, Daiichi Pharmaceutical, Tokyo, Japan) with a volume of 0.2 mL/kg weight was injected at 2.0 mL/s into the antecubital vein, followed by a 20-mL saline flush using a power injector (Sonic Shot, Nemoto, Tokyo, Japan).

Supine-position MRI with a 1.5-T imager (Magnetom, Siemens Medical Systems) was performed with the arm raised using a flexible body surface coil to achieve the same position as that used in US. Acquisition was performed as described previously (Nakano et al. 2009).

The BI-RADS (2013) lexicon was used to evaluate lesion size and type and to assess kinetic curves (American College of Radiology 2013).

Ultrasound

All US examinations were performed by a single experienced surgeon (S.N.). A 13-MHz linear-array probe was used in all patients (EUB-8500 and HIVISION Ascendus, Hitachi Aloka Medical Corp., Tokyo, Japan). US was performed on patients were in the supine position with one arm raised. Sagittal images were obtained in overlapping planes, and the resulting images were supplemented by transverse and oblique scans.

RVS-derived skin marking

The RVS system (Hitachi Aloka Medical) consisted of a US scanner, magnetic field generator, magnetic sensor and workstation with built-in RVS software (Fig. 1). The breast MRI volume data for each enhancing phase were initially transferred to the workstation. The magnetic sensor installed on the probe tip sensed the magnetic field and detected the position and motion of the probe while it was scanning. The 3-D position of the probe was transmitted to the workstation. The workstation computed the positional information and displayed an MRI-multiplanar

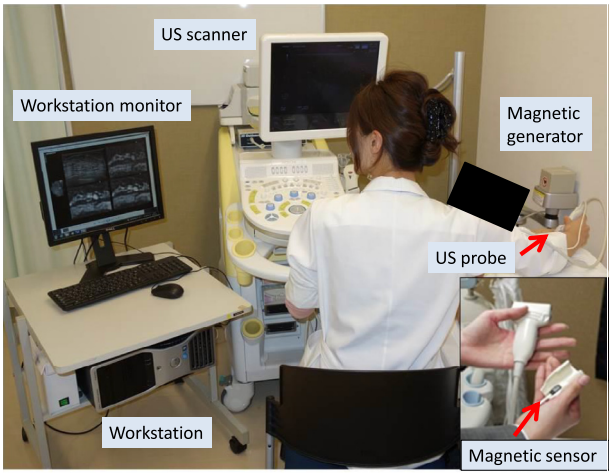

Fig. 1. Equipment and operating technique for real-time virtual sonography system (prototype) in the outpatient consultation room. US = ultrasound.