

Comparison of the background echotexture between automated breast ultrasound and handheld breast ultrasound

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Abstract

This study aimed to compare the background echotexture (BE) between automated breast ultrasound (ABUS) and handheld breast ultrasound (HHUS) and evaluate the correlation of BE with mammographic (MG) density and background parenchymal enhancement (BPE) on magnetic resonance imaging (MRI). A total of 212 women with newly diagnosed breast cancer who had undergone preoperative ABUS, HHUS, MG, and MRI were included. Two breast radiologists blinded to the menopausal status analyzed the BE of the contralateral breasts of the patients with breast cancer in consensus. The MG density and BPE of breast MRI on the radiologic reports were compared with the BE in the ultrasound. We used the cumulative link mixed model to compare the BE and Spearman rank correlation to evaluate the association between BE with MG density and BPE. BE was more heterogeneous in ABUS than in HHUS ($P < .001$) and in the premenopausal group than in the postmenopausal group ($P < .001$). The heterogeneity of BE in the premenopausal group was higher with ABUS than with HHUS ($P = .013$). BE and MG density showed a moderate correlation in the postmenopausal group, but a weak correlation in the premenopausal group. BE and BPE showed moderate correlations only in the premenopausal group. ABUS showed a more heterogeneous BE, especially in the premenopausal group. Therefore, more attention is required to interpret ABUS screening in premenopausal women.

Abbreviations: ABUS = automated breast ultrasound, BE = background echotexture, BPE = background parenchymal enhancement, DCE = dynamic contrast-enhanced, US = ultrasonography, BI-RADS = American College of Radiology's Breast Imaging Reporting and Data System, HHUS = handheld breast ultrasound, MG = mammography, MRI = magnetic resonance imaging, RS = Spearman rho coefficient.

Keywords: breast, magnetic resonance imaging, mammography, menopause, ultrasonography

1. Introduction

Breast cancer is the most common type of cancer in women, with >2 million newly diagnosed cancer patients and 600,000 cancer-related deaths worldwide annually. Therefore, early detection through screening, followed by proper treatment, is of utmost importance.^[1] Ultrasound (US) is widely used in a variety of medical fields,^[2,3] and especially in breast, it is an essential imaging modality for evaluating breast lesions. Not only for diagnostic purposes for breast lesions but also bilateral whole-breast US is used frequently for supplemental screening of dense breasts.^[4-6] However, the diagnostic performance and cancer detection rate of screening breast US vary widely across many studies.^[4-8] Background echotexture (BE) on breast US is considered one of the factors influencing the diagnostic performance of breast US screening.^[9] According to the American College of Radiology's

Breast Imaging Reporting and Data System (BI-RADS), the information regarding BE of US should be stated in the radiologic report of screening breast US, since heterogeneous BE of the breast may reduce the sensitivity of US by masking suspicious lesions.^[10]

Several studies have described the relationship between BE on breast US, mammographic (MG) density, and background parenchymal enhancement (BPE) on magnetic resonance imaging (MRI).^[9,11-15] According to these reports, BE showed a positive correlation with BPE,^[11,13-15] and the relationship between BE and MG density is controversial.^[9,12,15,16] Additionally, the presence or absence of menopause affects BE, as premenopausal women tend to have more heterogeneous BE.^[9,14,15] However, most of these previous studies analyzed data from BE using conventional handheld ultrasound (HHUS).

Automated breast ultrasound (ABUS), a special breast US that automatically scans whole breast using a wide transducer,

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provides a standardized and uniform US image.^[17] The use of ABUS has increased, especially in screening breast US for dense breasts.^[17,18] ABUS has the advantage of covering larger areas of breast tissue, providing additional coronal and sagittal images to better demonstrate breast anatomy and reduce operator dependence when compared to HHUS.^[19] ABUS also provides reproducibility for focal lesions and shows substantial agreement on US features of focal lesions between different radiologists.^[20,21] Considering the growing use of ABUS in breast cancer screening, more information about BE on ABUS is needed. Knowledge of BE on ABUS compared with HHUS is helpful for lesion detection in screening breast US using ABUS, US follow-up using ABUS and HHUS, and integration of imaging interpretation of ABUS with other modalities. However, to our knowledge, despite the development and growing use of ABUS, there are currently no studies comparing the BE between ABUS and HHUS, or the correlation of BE on ABUS with other imaging modalities. Therefore, the present study aimed to compare BE between ABUS and HHUS and evaluate the correlation of BE on ABUS with MG density and BPE on MRI.

2. Methods

2.1. Study population

The present study was approved by our institutional review board (IRB No. 2020-06-085-001), and the requirement for informed consent was waived because of the retrospective nature of the study. Newly diagnosed breast cancer patients who underwent preoperative ABUS, HHUS, MG, and MRI between September 2019 and April 2020 were included in the present study. The exclusion criteria for performing ABUS were as follows: pregnancy or lactation, history of breast cancer, having undergone or undergoing chemotherapy at the time of the imaging, scars from previous breast surgery, breast with a large palpable mass (>5 cm), and breast augmentations since they had contraindications to ABUS or other factors that could affect breast BE. A total of 212 women (mean age, 49.9 years; range, 27–69 years) were included in the present study, consisting of 122 premenopausal (mean age, 43.5 years; age range, 27–54 years) and 90 postmenopausal (mean age, 58.7 years; age range, 49–69 years).

2.2. Image examination

2.2.1. Handheld breast ultrasound Bilateral whole-breast HHUS was performed by one of 5 breast imaging radiologists who had 10 to 25 years of experience in breast US, using an IU-22 unit with a 5- to 12-MHz linear transducer (Philips Medical Systems, Bothell, WA), RS80A system with 3- to 12-MHz linear transducer (Samsung Medison Co., Ltd., Seoul, Korea), or an Aixplorer System with a 15- to 4-MHz linear transducer (Supersonic Imagine, Aix-en-Provence, France). All US examinations were performed in the supine position, and both arms were elevated. The scanning depth was 3–5 cm, covering the skin to the chest wall muscle. A band of the focal zone was placed at the center of the breast parenchyma. Mild manual compression with the transducer was applied during the US examinations. Four quadrants on each breast, the subareolar area, and both axillae were examined and recorded for each patient. The radiologists were aware of both the clinical and MG findings of the patients at the time of US examinations. All radiologists reached a consensus on the BE and captured representative images for background parenchymal echotexture during the examination.

2.2.2. Automated breast ultrasound Bilateral whole-breast ABUS was performed on the same day as HHUS by a well-trained technologist who specialized in both MG and breast

ABUS, using an Invenia ABUS system with an automated 6 to 15 MHz, 15.3 cm wide-field view transducer (Reverse Curve Ultra-broadband Transducer, GE Healthcare, Sunnyvale, CA). Bilateral whole breasts were scanned using anteroposterior, lateral, and medial scans, and additional scans were performed if additional breast tissue was not included in the 3 basic scans. Patients were positioned the same as during the HHUS, and the scanning depth was 4–5 cm, covering the skin to the chest wall muscle including pectoralis major and intercostal muscles. There was no focal setting in the ABUS machine. After the image acquisition, postprocessing algorithms were applied, based on the location of the nipple, to improve the diagnostic information quality, and the acquired volume data were automatically sent from the ABUS scanner to the review workstation. The volume data were reviewed in axial, sagittal, and coronal planes on the review workstation with a 0.5-mm slice interval. The technologist who performed the ABUS was aware of the patients' clinical findings, but not the MG densities, at the time of the US examinations.

2.2.3. Mammography All patients underwent digital mammography on the same day as breast US. Two standard imaging planes (mediolateral oblique and craniocaudal) were obtained in the bilateral breasts using Selenia Dimensions (Hologic, Bedford, MA) or Mammomat Revelation (Siemens, Healthineers, Germany).

2.2.4. Magnetic resonance imaging Bilateral breast MRI was also performed within 1 week of breast US examination. MRI scanning was performed using a 3.0T Achieva scanner (Philips Medical Systems, Best, The Netherlands) with a dedicated bilateral phase array breast coil in the prone position. The MRI protocol consisted of turbo spin-echo T1- and fat-suppressed T2-weighted sequences in the axial plane and fat-suppressed 3-dimensional dynamic contrast-enhanced (DCE) sequence. Axial DCE-MRI was performed with one precontrast and 5 postcontrast dynamic series. A 0.1 mmol/kg bolus of gadobutrol (Gadovist; Bayer Healthcare, Berlin, Germany) was injected, followed by a 20-mL saline flush. Dynamic images were acquired from 30 seconds, 5 times every 60 seconds, with a gradient echo sequence (eTHRIVE). Images were obtained under the following parameters: repetition time/echo time (ms), 5.8/2.9; 1.5 mm sections with no gap; flip angle, 24°; matrix size, 512×512; and field of view, 33×33 cm. Reformatted sagittal images and reformatted 3-dimensional maximum intensity projection images were also obtained.

2.3. Image evaluation

Breast US images were analyzed for BE in consensus by 2 radiologists, with 10 and 19 years of experience in breast imaging, blinded to the patients' age, menopausal state, or findings of other imaging modalities, such as MG and breast MRI. They reviewed and assessed the BE on HHUS and ABUS in patients with a 1-week interval. BE was determined in the same axial plane of both the HHUS and ABUS images, and the contralateral breast of the breast cancer was chosen for the assessment.

BE was classified into homogeneous-fat BE, homogeneous-fibroglanular BE, and heterogeneous BE, based on the BI-RADS lexicon.^[10] Homogeneous-fat BE was defined as breast tissue consisting of fat lobules with uniform echogenic bands, homogeneous-fibroglanular BE as thick echogenic fibroglanular tissue beneath the premammary fat layer, heterogeneous BE as small increased and decreased echogenic areas scattered in the parenchyma, and with possible shadowing between the premammary fat layer and parenchyma interface.^[10]

MG densities and BPE on breast MRI were analyzed from the radiologic reports that had been made by one of 5 breast radiologists and compared with BE in the US. MG density was categorized as almost entirely fatty; scattered fibroglanular; heterogeneously

dense, which may obscure small masses; or extremely dense, which lowers the sensitivity of MG. BPE on breast MRI was assessed based on the maximum intensity projection images created from postprocessing of the first post-contrast-enhanced images, and was categorized as minimal, mild, moderate, or marked.

2.4. Data and statistical analysis

We compared the BE between ABUS and HHUS using a cumulative link mixed model. The association between BE from each US method and MG density or BPE on MRI and that between MG density and BPE was evaluated using the Spearman rank correlation coefficient. To interpret the Spearman rho (R_s) coefficient, we used the following benchmarks: 0.10 to 0.30 = weak correlation, 0.31 to 0.60 = moderate correlation, 0.61 to 0.90 = strong correlation, and 0.91 to 1.00 = perfect correlation.^[21] Additionally, we divided patients into pre- and postmenopausal groups and performed a secondary analysis to determine whether the above items differed based on menopausal status.

Statistical analysis was performed using SAS (version 9.4; SAS Institute, Cary, NC) and R version 3.6.1 (Vienna, Austria; <http://www.R-project.org/>), with a *P* value < .05, indicating a statistically significant difference.

3. Results

The BE data on breast US, MG density, and BPE on MRI for all patients are presented in Table 1, and the comparison of BE between ABUS and HHUS is shown in Table 2. Overall, ABUS images presented a more heterogeneous BE than HHUS images (*P* < .001). When we graded BE as homogeneous-fat, homogeneous-fibroglandular, or heterogeneous, 75.0% of patients had the same BE category on both ABUS and HHUS, 22.2% of the patients were categorized as high grade (more heterogeneous tendency) on ABUS (Fig. 1), and 2.8% of the patients were

categorized as a low grade on ABUS. When compared based on menopausal status, the premenopausal group had a higher grade on BE than the postmenopausal group on both ABUS (68.0% vs 34.4%) and HHUS (44.3% vs 21.1%; *P* < .001), and there was a pronounced tendency to categorize BE as high grade on ABUS than on HHUS in the premenopausal group than in the postmenopausal group (*P* = .013).

Table 3 shows the correlation of BE on ABUS and HHUS with MG density and BPE on MRI. Overall, BE and MG density showed a moderate positive correlation (R_s = 0.499 on ABUS, R_s = 0.447 on HHUS, *P* < .001); however, this was due to the moderate correlation in the postmenopausal group (R_s = 0.556 on ABUS, R_s = 0.505 on HHUS, *P* < .001) but not in the premenopausal group (R_s = 0.227 on ABUS, *P* = .018; R_s = 0.244 on HHUS, *P* = .007). Overall, BE on breast US and BPE on MRI showed a moderate positive correlation (R_s = 0.355 on ABUS, R_s = 0.349 on HHUS, *P* < .001), which was due to the moderate correlation of HHUS (R_s = 0.319, *P* < .001) and weak correlation of ABUS in the premenopausal group (R_s = 0.256, *P* = .004). However, there was no correlation between BE and BPE in the postmenopausal group (R_s = 0.090 on ABUS, *P* = .401; R_s = 0.084 on HHUS, *P* = .431).

4. Discussion

Although there have been several studies regarding BE on ABUS and HHUS individually,^[9,12,16,22] the present study is the first to perform a comparative analysis of BE between ABUS and HHUS. The results from our study revealed a tendency toward more heterogeneous BE on ABUS than on HHUS, showing that 73.1% of the patients had the same category of BE on both US examinations, and 22.6% of them had more heterogeneous BE on ABUS. Heterogeneous BE is defined as scattered small hypo- or hyperechoic areas in the parenchyma with shadowing below the interface of the parenchyma and fat lobules.^[10] ABUS, using

Table 1. Background echotexture of breast ultrasound, mammographic density, and background parenchymal enhancement of magnetic resonance imaging of the patients.

| Modality | ABUS echotexture | | | HHUS echotexture | | | MG density | | | | BPE of MRI | | | |
|-----------------------------|------------------|---------|--------|------------------|---------|--------|------------|-------|-------|-------|------------|-------|----------|--------|
| | Homo-fat | Homo-FG | Hetero | Homo-fat | Homo-FG | Hetero | A | B | C | D | Minimal | Mild | Moderate | Marked |
| All (% of total) | 20 | 78 | 114 | 17 | 122 | 73 | 6 | 46 | 90 | 70 | 84 | 61 | 43 | 24 |
| | -9.4 | -36.8 | -53.8 | -8 | -57.5 | -34.4 | -2.8 | -21.7 | -42.5 | -33 | -39.6 | -28.8 | -20.3 | -11.3 |
| Premenopausal (% of total) | 0 | 39 | 83 | 0 | 68 | 54 | 0 | 10 | 52 | 60 | 22 | 37 | 41 | 22 |
| | 0 | -32 | -68 | 0 | -55.7 | -44.3 | 0 | -8.2 | -42.6 | -49.2 | -18 | -30.3 | -33.6 | -18 |
| Postmenopausal (% of total) | 20 | 39 | 31 | 17 | 54 | 19 | 6 | 36 | 38 | 10 | 62 | 24 | 2 | 2 |
| | -22.2 | -43.3 | -34.4 | -18.9 | -60 | -21.1 | -6.7 | -40 | -42.2 | -11.1 | -68.9 | -26.7 | -2.2 | -2.2 |

A = almost entirely fatty, ABUS = automated breast ultrasound, B = scattered areas of fibroglandular density, BPE = background parenchymal enhancement, C = heterogeneously dense, D = extremely dense, FG = fibroglandular, HHUS = handheld breast ultrasound, Hetero = heterogeneous, Homo = homogeneous, MG = mammography, MRI = magnetic resonance imaging.

TABLE 2. Background echotexture assessment in automated breast ultrasound and handheld breast ultrasound.

| Patients | ABUS = HHUS | ABUS > HHUS | ABUS < HHUS | <i>P</i> value |
|-----------------------------|----------------|---------------|-------------|----------------|
| All (% of total) | 159/212 (75.0) | 47/212 (22.2) | 6/212 (2.8) | <.001 |
| Menopausal state | | | | <.001 |
| Premenopausal (% of total) | 87/122 (71.3) | 32/122 (26.2) | 3/122 (2.5) | <.001 |
| Postmenopausal (% of total) | 72/90 (80.0) | 15/90 (16.7) | 3/90 (3.3) | .08 |

=, same background echotexture, > = high-grade background echotexture (more heterogeneous tendency), < = low-grade background echotexture (less heterogeneous tendency), ABUS = automated breast ultrasound, HHUS = handheld breast ultrasound, US = ultrasound.

a 15.3-cm wide-view transducer, has the advantage of being able to evaluate a wider range of breast tissue at once during image interpretation. However, when radiologists read a wider range of images at a glance, the presence of a small heterogeneous area may lead to the categorization of the entire BE as heterogeneous.

We attempted to perform uniform compression during ABUS scanning, but it may not be possible to perform proper compression on the whole breasts, similar to the HHUS scanning, in which we can perform appropriate manual compression for each small area by changing the strength of compression according to the characteristics of the location or changing the direction of the transducer. Additionally, ABUS images have more shadows than HHUS because the reflection at an acute angle to the US beam is less flattened by the transducer on ABUS

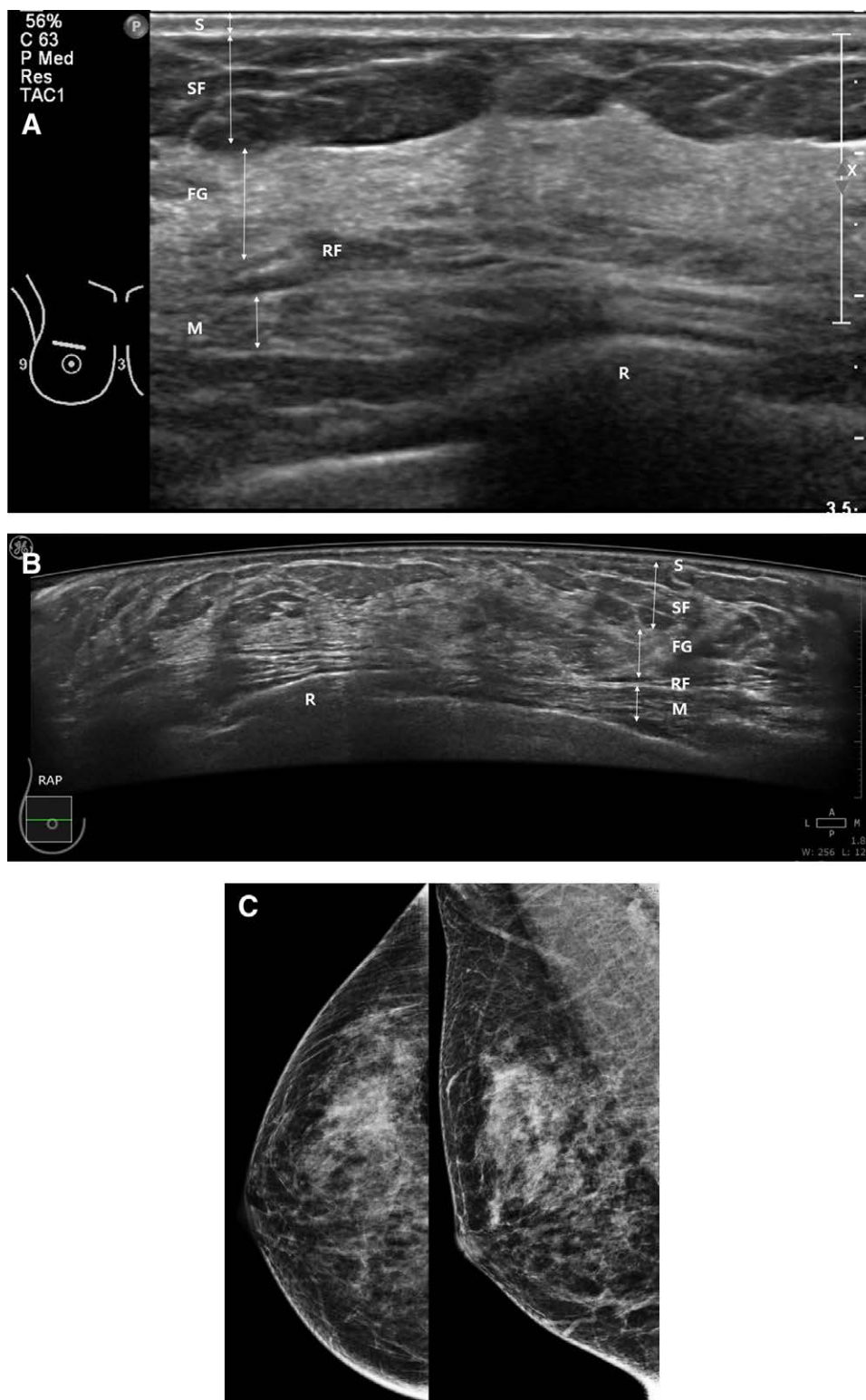


Figure 1. A 46-year-old premenopausal woman was diagnosed with left breast cancer. (A) We assessed background echotexture of the right breast as homogeneous-fibroglandular on HHUS. (B) ABUS image of the same area shows heterogeneous background echotexture. (C) Mammography of the right breast shows heterogeneously dense breast composition, and (D) maximum intensity projection of breast MRI image shows a moderate level of background parenchymal enhancement. ABUS = automated breast ultrasound, FG = fibroglandular tissue, HHUS = handheld breast ultrasound, M = chest wall muscles, MRI = magnetic resonance imaging, S = skin, SF = subcutaneous fat, RF = retromammary fat, R = rib.

than on HHUS.^[23] Since we used a wide transducer on ABUS, there are more parts of the breast where contact or compression is not as appropriate as on HHUS, especially on the lateral side of the breast. Premenopausal women are known to have more heterogeneous BE due to the hormone effect,^[9,13–15] and

hormone-stimulated rich glandular tissue may cause more heterogeneous BE on ABUS for the same reason.

ABUS tended to show more heterogeneous BE than HHUS, but when compared to MG density and BPE on MRI, the correlation coefficients of both types of US were almost similar.

Table 3. Spearman rank correlation coefficient (RS) between background echotexture of each ultrasound and mammographic density or background parenchymal enhancement of magnetic resonance imaging.

| Patients | US | MG density | | BPE of MRI | |
|----------------|------|------------|----------------|------------|----------------|
| | | R_s | <i>P</i> value | R_s | <i>P</i> value |
| All | ABUS | 0.499 | <.001 | 0.355 | <.001 |
| | HHUS | 0.447 | <.001 | 0.349 | <.001 |
| Premenopausal | ABUS | 0.227 | .018 | 0.256 | .004 |
| | HHUS | 0.244 | .007 | 0.319 | <.001 |
| Postmenopausal | ABUS | 0.556 | <.001 | 0.090 | .401 |
| | HHUS | 0.505 | <.001 | 0.084 | .431 |

ABUS = automated breast ultrasound, BPE = background parenchymal enhancement, HHUS = handheld breast ultrasound, MG = mammography, MRI = magnetic resonance imaging, R_s = Spearman rank correlation coefficient, US = ultrasound.

Concordant with the results of previous studies,^[13–15] there were significant correlations between BE on both types of US and BPE on MRI but only in the premenopausal group. Histologically, stromal fibrous tissue is an important factor in BE, as the tissue consists of dense interlobular stromal fibrous tissue and loose intralobular stromal fibrous tissue located in the periductal area, and lies within the lobules.^[24,25] This is important in breast US because the dense stromal fibrous tissue is usually hyperechoic, and loose stromal fibrous tissue is iso- or hypoechoic, which can appear as heterogeneous BE.^[26,27] The balance between dense stromal fibrous tissue and loose stromal fibrous tissue is determined by hormonal state and age^[26]; thus, a more heterogeneous BE indicates that the breast parenchyma has rich glandular tissue and loose stromal fibrous tissue. BPE on MRI is also dependent on the hormonal state and menstrual cycle^[28,29]; therefore, the correlation between BE and BPE in the premenopausal group is understandable. However, the hormonal state did not affect the postmenopausal group. BPE of MRI and BE of US in the postmenopausal group may be characteristic of the patient's own glandular tissue and stromal fibrous tissue. Therefore, there was no correlation between the BPE of MRI and BE of US in our study. Furthermore, while previous studies have reported an association between BE and BPE in the postmenopausal group, BE was divided into homogeneous and heterogeneous, but our study divided BE into homogeneous-fat, homogeneous-fibroglandular, and heterogeneous.^[14,15] Based on our results, we suggest that the heterogeneous BE of premenopausal women could be affected by physiologic or hormonal changes that cause BPE on MRI, while the heterogeneous BE of postmenopausal women can be affected by breast density caused by the amount of remnant fibroglandular tissue rather than the hormonal effects.

In previous studies, the relationship between BE and MG density was controversial, but 2 recent studies have reported a positive correlation between BE and MG density on both HHUS and ABUS.^[9,16] In the present study, the postmenopausal group showed a moderate correlation between BE and MG density. In the postmenopausal state, the amount of loose stromal fibrous tissue is reduced, resulting in dense stromal fibrous tissue occupying a larger portion of the parenchyma. Therefore, the amount of dense stromal fibrous tissue is a factor that determines both MG density and BE of the US, resulting in a positive relationship between the 2. While patients in the postmenopausal group had various MG densities, most premenopausal patients had increased MG densities. Because some dense breasts showed homogeneous-fibroglandular BE in the US, the degree of correlation between MG density and BE was higher in the postmenopausal group.

Several previous studies have reported no correlation between BPE on MRI and MG density.^[13–15,30,31] In the present

study, we found no significant correlation between the premenopausal and postmenopausal groups; however, the overall results showed an unexpected positive correlation. We felt that this was the result of a statistical error caused by the correlation between BE and BPE in the premenopausal group and a correlation between BE and MG density in the postmenopausal group.

The present study had some limitations. First, this was a single-center study of a population of Korean women with breast cancer, who typically have a higher rate of dense breast tissue. Therefore, the results may differ in other countries and races. However, since screening breast ABUS is used as a supplemental screening tool in dense-breasted women with lower mammography sensitivity, our BE analysis may still be helpful in screening ABUS. Second, we used a single-model ABUS system. Third, we performed a breast MRI examination without considering the patient's menstrual cycle in the premenopausal group. Most patients underwent breast MRI on the same day as breast US or a few days later.

We conclude that ABUS has a more heterogeneous BE than HHUS, especially in the premenopausal group. Because heterogeneous BE may reduce the sensitivity of US, our results suggest that more attention should be paid when interpreting screening ABUS in premenopausal women.

Author contributions

Jieun Kim: data curation, methodology, visualization, writing - original draft.

Eun Young Ko: investigation, formal analysis, methodology, project administration, visualization, supervision, writing - review and editing.

Boo-Kyung Han: supervision, writing - review and editing.

Eun Sook Ko: investigation, resources.

Ji Soo Choi: investigation, resources.

Ko Woon Park --> investigation, resources.

Haejung Kim --> investigation, resources.

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