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ORIGINAL ARTICLE

Non-calcified ductal carcinoma in situ of the breast: comparison of diagnostic accuracy of digital breast tomosynthesis, digital mammography, and ultrasonography

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Abstract

Background To retrospectively compare the diagnostic accuracy of digital breast tomosynthesis (DBT), digital mammography (DM), and ultrasonography (US) in non-calcified ductal carcinoma in situ (DCIS, include DCIS with micro-invasion).

Patients and methods Ninety-eight patients with non-calcified DCIS (include DCIS with micro-invasion) were enrolled in our study. Breast carcinoma in situ was confirmed by surgical pathologic evaluation. Our Institutional Review Board granted approval and the participating women provided written informed consent. The imaging findings were evaluated according to the Breast Imaging Reporting and Data System (BI-RADS) of the American College of Radiology (ACR) by comparing the differences in the detection rate and diagnostic accuracy among the three techniques in all cases, in dense breasts, and in non-dense breasts.

Results The detection rates of DBT, DM, and US for non-calcified DCIS in all cases were 83.7, 68.4, and 94.9%, respectively, and in patients with dense breasts were 81.2, 63.8, and 95.0%. The detection rate of US was higher than DBT, which, in turn, was higher than DM both in all cases and in dense breasts. Pairwise comparisons among the three techniques showed that the differences were statistically significant ($P = 0.000$ and $P = 0.000$, respectively). The experts identified a case as abnormal for all criteria (BI-RADS score of 4B-5) in 68.4% of ratings using DBT, 43.9% of ratings using DM, and 66.3% of ratings using US; for dense breasts, the positive identification rates were 62.5% of ratings using DBT, 41.2% of ratings using DM, and 61.2% of ratings using US. The diagnostic accuracy of DBT and US was significantly higher than that of DM in all cases ($P = 0.001$ and $P = 0.006$, respectively) and in dense breasts ($P = 0.007$ and $P = 0.011$, respectively). The diagnostic accuracy of DBT was slightly higher than US in all cases and in dense breasts, but the difference was not statistically significant ($P = 0.761$ and $P = 0.871$, respectively). By DBT, most non-calcified cases of DCIS presented as a mass lesion (54.9%) with an irregular shape (46.7%), indistinct margin (53.3%), and isodense composition (71.1%). Using US, 72 of 93 patients (77.4%) were shown to have a mass. Most mass lesions had an irregular shape (83.3%), indistinct margin (55.5%), and parallel the skin (82.8%).

Conclusion DBT and US gave better detection rates and diagnostic accuracy for non-calcified DCIS compared with DM in all cases and in dense breasts. The detection rate of DBT was lower than that of US in all cases and in dense breasts. The diagnostic accuracy of DBT was slightly higher than that of US in all cases and in dense breasts, but the difference was not statistically significant. Imaging findings for non-calcified DCIS were relatively non-specific.

Keywords Ductal carcinoma in situ · Ultrasonography · Mammography · Tomosynthesis · Diagnostic accuracy

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Introduction

Breast carcinoma in situ is a pre-cancerous condition. In recent years, ductal carcinoma in situ (DCIS) has been encountered more frequently because of the widespread use of mammographic screening in asymptomatic women. DCIS accounts for 12%–15% of newly diagnosed breast cancer each year in the United States [1]. The mammographic features of DCIS have been well described in the literature, with micro-calcifications being the dominant feature, but 10%–20% of patients with DCIS have no calcifications [2]. Digital breast tomosynthesis (DBT) is a new digital mammography technique. Obscuring of the image by surrounding and overlying structures is resolved, at least in part, by DBT [3]. Rafferty [4] reported that the diagnostic accuracy of DBT is superior to that of digital mammography (DM) for non-calcified lesions. However, to our knowledge, the differences between DBT and US for non-calcified DCIS have not been reported. Therefore, the purpose of our study was to retrospectively evaluate the imaging findings of non-calcified DCIS using DBT, DM, and US, and to compare the differences among the three techniques.

Materials and methods

Patients

Our study was approved by the Institutional Review Board. Participating women provided written informed consent. At our hospital, the combination of DM, DBT, and US examinations of the affected breast was approved by the hospital ethical committee as the routine clinical protocol for preoperative breast patients. Between March 2012 and July 2015, we enrolled 602 patients with breast carcinoma in situ through the pathologic diagnostic system in our hospital. After exclusion of 10 patients with lobular carcinoma in situ and 52 patients whose final pathology resulted in a diagnosis of intraductal papilloma with carcinoma in situ, 540 patients with DCIS or DCIS patients with micro-invasion were included in our study. We collected mammography images of patients with DCIS from the picture archiving and communication system (PACS) and collected US images from the PACS workstation provided in each US examination room using the hospital number. Patients with calcified DCIS visible by mammography were excluded by two radiologists who had 3–20 years (average, 16 years) of experience in mammographic imaging and had no access to information on the final surgical histopathologic results or the patient medical records; as a result, 98 patients with non-calcified DCIS were finally included in our study. Mammography images were analyzed and the BI-RADS final assessment category was classified independently by two radiologists who participated in the selection of the non-calcified DCIS patients and were blinded to the clinical or histopathologic findings; US images were analyzed by another two radiologists. The radiologists reached a consensus through discussion when their opinions differed. Of the 98 cases, 58 patients were diagnosed as DCIS and 40 as DCIS with micro-invasion (<1 mm). Participants underwent two-view DBT of the affected breast and two-view DM of both breasts. Complete DBT, DM, and US data were available for all 98 patients. We did not conduct further study involving MRI findings, because only six patients required an MRI scan. All patients were females. The average patient age was 50 years (range, 29–72 years). The maximum diameter of masses evaluated by DBT ranged from 0.9 to 5.7 cm (mean, 2.6 cm). In our study, 82 of 98 (83.7%) patients had clinical symptoms, and of these, 77 patients (78.6%) presented with a palpable mass, 13 (13.3%) had a nipple discharge (bloody in seven patients, yellow in two patients, and ivory-white in three patients), and 3 presented with localized pain. Of all 98 patients, 36 patients had right breast involvement, 62 patients had left breast involvement, 57 had upper outer quadrant involvement, 16 had lower outer quadrant involvement, 12 had upper inner quadrant involvement, 8 had lower inner quadrant involvement, and 5 had involvement posterior to the nipple. A total of 98 lesions were confirmed through pathologic evaluation of surgical specimens. US-guided core biopsy was performed pre-operation on 67 patients. The biopsy pathology of 59 patients revealed DCIS, with dilated ducts in three patients, intraductal papillomas in two patients, a papillary neoplasm in one patient, and adenopathy in two patients. The remaining 31 patients preferred to accept the surgical biopsy directly.

Digital breast tomosynthesis (DBT) and digital mammography (DM)

DBT and DM examination was performed using one digital mammography unit (Selenia Dimensions System, Hologic, Bedford, MA, USA) before surgery. DM examination consisted of the mediolateral oblique (MLO) and craniocaudal (CC) views of the bilateral breasts. The affected breast MLO and CC views were chosen for the DBT examinations. The examination was performed in combo pattern (able to do digital breast tomosynthesis and digital mammography at the same time) for the affected breast and conventional pattern for the normal breast. The mammographic findings were classified into mass, focal asymmetry, architectural distortion, or others. If a mass was present on the mammogram, the shape (oval, round, lobular, or irregular), margin (indistinct, spiculated, circumscribed, or micro-lobulated), and density (high density, isodense, or low density) were evaluated according to the Breast Imaging Reporting and Data System by the American College of Radiology (ACR BI-RADS, 2013, fifth edition).

Ultrasonography (US)

US was performed using an ACUSON-S2000 (Siemens Medical, Malvern, PA, USA) or a HITACHI EBU-7500 (Hitachi Medical, Tokyo, Japan) color Doppler diagnostic instrument. The bilateral breast US scanning technique was standardized to include both the breast parenchyma and the lower axillary areas. The sonographic findings were classified as negative, a mass, or a non-mass lesion. In patients with masses, we recorded the sonographic findings of the lesions according to the ACR BI-RADS, making note of the shape (oval, round, lobulated, or irregular), margin (circumscribed, not circumscribed, spiculated, or angular), orientation (parallel to the skin or non-parallel), echo pattern (isoechoic, hypoechoic, or hyperechoic), and posterior acoustic features (none, enhancement, shadowing, or combined).

Image analysis

Radiologic findings were evaluated according to the ACR BI-RADS. The BI-RADS 1–5 classification was used for mammography and ultrasonography to assess the probability of malignancy. The classifications 0 and 6 were not applicable, because this was a retrospective study. In our study, BI-RADS 4B, 4C, and 5 were regarded to be in agreement with the pathologic findings, BI-RADS 1, 2, 3, and 4A were considered to be negative. BI-RADS 4A means low suspicion of malignancy according to the Breast Imaging Reporting and Data System of the American College of Radiology. Though histological diagnosis is necessary, the possibility of a benign lesion is much larger than the possibility of a malignant lesion. Therefore, we regarded BI-RADS 4A as negative in our analysis to avoid the dilution of the criteria of malignancy by a high number of benign lesions. The patients with BI-RADS categories 4 and 5 lesions visualized by DM, DBT or US were recommended for surgery, but in our study, some patients in BI-RADS category 3 also preferred to undergo surgery rather than regular follow-up. DBT and DM images were reviewed by two radiologists who had 3–20 years (average, 16 years) of experience in breast imaging to reach a consensus reading. The senior radiologists with 20 years of experience had non-domestic training for 3 years to acquire breast imaging diagnostic skills and trained another radiologist after returning. US images were reviewed by two radiologists who had 5–20 years (average, 12 years) of experience in breast US to reach a consensus reading of images that were collected by the PACS workstation. Two radiologists rated each breast for density based on the BI-RADS categories, as follows: (a) almost entirely fatty; (b) scattered fibroglandular densities; (c) heterogeneously dense; and (d) extremely dense. BI-RADS categories (c) and (d) were classified as dense breasts, while BI-RADS (a) and (b) were classified as fatty breasts.

Statistical analysis

Statistical analysis was performed using statistical software (SPSS version 17.0, SPSS Inc., Chicago, IL, USA), to analyze whether there were differences among DBT, DM, and US in the detection rate and diagnostic accuracy of non-calcified DCIS. The χ^2 test was used for analysis of non-parametric independent variables. Findings with $P < 0.05$ were indicative of a statistically significant difference. $n \geq 40$ and $1 \leq T < 5$ were considered to use the corrected χ^2 test when performing a comparison between two techniques. $n < 40$ or $T < 1$ was analyzed by Fisher' s exact test to determine statistical significance, and P values lower than 0.017 were considered statistically significant.

Results

Detection rate and diagnostic accuracy of DBT, DM, and US for non-calcified DCIS

The detection rate of DBT, DM, and US for non-calcified DCIS was 83.7, 68.4, and 94.9%, respectively, and the differences between the three techniques were statistically significant ($\chi^2 = 23.877$, $P = 0.000$). Pairwise comparisons among the three techniques were also statistically significant (Table 1).

The diagnostic accuracy of DBT, DM, and US for non-calcified DCIS was 68.4, 43.9, and 66.3%, respectively, and there were statistically significant differences among the three techniques ($\chi^2 = 15.021$, $P = 0.001$). The diagnostic accuracy of DBT and US was higher than that of DM, and the difference was statistically significant (Table 1). The diagnostic accuracy of DBT was slightly higher than US, but the difference was not statistically significant. The different BI-RADS categories of DBT, DM, and US for non-calcified DCIS are shown in Table 2. Based on US, 25 of 98 patients with non-calcified DCIS were assigned to BI-RADS category 4A, which was different compared to those assigned to BI-RADS rating 4A by DBT ($\chi^2 = 5.630$, $P = 0.018$).

Table 1 Pairwise comparison of the detection rate and diagnostic accuracy among three techniques for non-calcified DCIS

Comparative group	Detection rate	Omission diagnostic rate	χ^2	P	Diagnostic accuracy	False-negative rate	χ^2	P
DM and DBT			6.297	0.012*			11.934	0.001*
DM	68.4% (67/98)	31.6% (31/98)			43.9% (43/98)	56.1% (55/98)		
DBT	83.7% (82/98)	16.3% (16/98)			68.4% (67/98)	31.6% (31/98)		
DBT and US			6.453	0.011*			0.093	0.761
DBT	83.7% (82/98)	16.3% (16/98)			68.4% (67/98)	31.6% (31/98)		
US	94.9% (93/98)	5.1% (5/98)			66.3% (65/98)	33.7% (33/98)		
DM and US			23.003	0.000*			9.981	0.002*
DM	68.4% (67/98)	31.6% (31/98)			43.9% (43/98)	56.1% (55/98)		
US	94.9% (93/98)	5.1% (5/98)			66.3% (65/98)	33.7% (33/98)		

DBT digital breast tomosynthesis, *DM* digital mammography, *US* ultrasonography

* Statistical significance: $P < 0.017$, using χ^2 test for comparison of proportion of two techniques

Table 2 Comparison of BI-RADS Categories of DBT, DM, and US for non-calcified DCIS

Technique	BI-RADS 1	BI-RADS 2	BI-RADS 3	BI-RADS 4A	BI-RADS 4B	BI-RADS 4C	BI-RADS 5
DBT	0	9	10	12	27	21	19
DM	0	21	17	17	32	8	3
US	0	5	3	25	23	22	20

DBT digital breast tomosynthesis, *DM* digital mammography, *US* ultrasonography

* Statistical significance: $P < 0.05$

Table 3 Pairwise comparison of the detection rate and diagnosis accuracy among three techniques for non-calcified DCIS in density breast

Comparative group	Detection rate	Omission diagnostic rate	χ^2	P	Diagnostic accuracy	False-negative rate	χ^2	P
DM and DBT			6.144	0.013*			7.235	0.007*
DM	63.8% (51/80)	36.2% (29/80)			41.2% (33/80)	58.8% (47/80)		
DBT	81.2% (65/80)	18.8% (15/80)			62.5% (50/80)	37.5% (30/80)		
DBT and US			7.227	0.007*			0.026	0.871
DBT	81.2% (65/80)	18.8% (15/80)			62.5% (50/80)	37.5% (30/80)		
US	95.0% (76/80)	5.0% (4/80)			61.2% (49/80)	38.8% (31/80)		
DM and US			23.861	0.001*			6.404	0.011*
DM	63.8% (51/80)	36.2% (29/80)			41.2% (33/80)	58.8% (47/80)		
US	95.0% (76/80)	5.0% (4/80)			61.2% (49/80)	38.8% (31/80)		

DBT digital breast tomosynthesis, *DM* digital mammography, *US* ultrasonography

* Statistical significance: $P < 0.017$, using χ^2 test for comparison of proportion of two technique

Comparison of the detection rate and diagnostic accuracy of DBT, DM, and US for non-calcified DCIS in breasts with different densities

Of all 98 patients, 80 were classified as having dense breasts and the remaining 18 patients had non-dense breasts. The detection rate and diagnostic accuracy of DBT, DM, and US for non-calcified DCIS in patients with dense breasts is shown in Table 3. The detection rates for DBT, DM, and US for non-calcified DCIS in dense breasts were 81.2, 63.8, and 95.0%, respectively, and pairwise comparison among the three techniques showed that the differences were statistically significant ($\chi^2 = 24.531$, $P = 0.000$). The diagnostic accuracy for DBT, DM, and US in dense breasts was 62.5, 41.2, and 61.2%, respectively, and the difference was statistically significant ($\chi^2 = 9.192$, $P = 0.010$). The diagnostic accuracy of both DBT and US were higher than that of DM in dense breasts, and the difference was statistically significant. The diagnostic accuracy of DBT was slightly higher than that of US, but the difference was not statistically significant. The detection rate for DBT, DM, and US in non-dense breasts was 94.4, 88.9, and 94.4%, and the diagnostic accuracy was 94.4, 55.5, and 88.9%, respectively; the difference was not statistically significant ($\chi^2 = 0.021$, $P = 0.990$; $\chi^2 = 1.200$, $P = 0.549$).

Imaging findings of non-calcified DCIS

By DBT, 16 patients had false-negative mammographic findings. The remaining 82 patients had abnormal findings, including masses in 45 patients (54.9%), focal asymmetry in 26 patients (31.7%), and architectural distortion in 11 patients (13.4%). By DM, 31 patients had false-negative mammographic findings. The remaining 67 patients had abnormal findings, including masses in 35 patients (52.2%), focal asymmetry in 22 patients (32.8%), and architectural distortion in 10 patients (14.9%). By US, 5 patients had false-negative findings, the remaining 93 patients had abnormal findings, and 72 of those 93 patients had masses. The remaining 21 patients had non-mass lesions, including architectural distortion in 11 patients, dilated ducts with nodules in 5 patients, and hypoechoic areas in 5 patients. The imaging findings of DBT, DM, and US for masses were shown in Table 4.

Table 4 Imaging findings of DBT, DM, and US in non-calcified DCIS presenting as masses

Characteristic	DBT (%)	DM (%)	US (%)
Shape			
Irregular	46.7% (21/45)	51.4% (18/35)	83.3% (60/72)
Round	26.7% (12/45)	14.3% (5/35)	2.8% (2/72)
Oval	17.8% (8/45)	17.1% (6/35)	5.6% (4/72)
Lobular	8.9% (4/45)	17.1% (6/35)	8.3% (6/72)
Margin			
Indistinct	53.3% (24/45)	65.7% (23/35)	55.5% (40/72)
Spiculated	24.4% (11/45)	8.6% (3/35)	1.4% (1/72)
Circumscribed	13.3% (6/45)	25.7% (9/35)	29.2% (21/72)
Micro-lobulated	8.9% (4/45)		
Angular			13.9% (10/72)
Density of lesions			
Isodense	71.1% (32/45)	68.6% (24/35)	
High density	28.9% (13/45)	31.4% (11/35)	
Posterior acoustic			
None			68.1% (49/72)
Shadowing			25.0% (18/72)
Enhancement			6.9% (5/72)
Orientation to skin			
Parallel			81.9% (59/72)
Non-parallel			18.1% (13/72)

DBT digital breast tomosynthesis, *DM* digital mammography, *US* ultrasonography

In this study, the frequency of irregularly shaped DCIS was higher in cases examined by US than in those examined by DBT, while round shapes were more prevalent in DBT than in US, and this difference was statistically significant ($\chi^2 = 17.478$, $P = 0.000$; $\chi^2 = 15.002$, $P = 0.000$). The frequency of oval and lobular shapes was higher in cases examined by DBT than US, but the difference was not statistically significant. The frequency of spiculated margins was higher in DBT than US, and the difference was statistically significant ($\chi^2 = 13.586$, $P = 0.000$). The frequency of indistinct margins of DCIS was higher in US images than DBT, but the difference was not statistically significant.

Discussion

DCIS of the breast is defined as malignant cells within the breast ducts without evidence of invasion through the basement membrane. Dershaw [5] reported that in 10%–20% of all patients, DCIS manifests as a mass, with asymmetric densities, or architectural distortion without calcifications. In our study, 18.1% of all patients were diagnosed with DCIS without calcification, consistent with the previous reports. The detection of DCIS lesions without calcification is difficult. Therefore, patients with non-calcified DCIS are more likely to see a physician with obvious clinical symptoms. Ikeda and Andersson [6] reported that 82% of patients with non-calcified DCIS were symptomatic. In our study, 83.7% of such patients were symptomatic (palpable mass, nipple discharge, or localized pain), which was consistent with the previous reports. The remaining 16 patients had seen a physician for a regular health examination. In this analysis, the percentage of micro-invasion in DCIS (40.8%) is much higher than in the literature (around 10%). The reasons for this could be the different genetic background, different selection criteria of patients (screening vs. symptomatic), or the variation of pathologists in the interpretation of criteria for micro-invasion [7].

As far as we know, visibility using tomosynthesis has been reported to be comparable to DM [8]. In addition, the visualization of detailed margins of the mass lesion by DBT and diagnosis according to the BI-RADS classification are superior to DM. Skaane [9] reported that DBT has a modest reduction in recall rate (15%) and a greater incidence of cancer detection (27%) compared with DM. In our study, the detection rate increased from 68.4% for DM to 83.7% for DBT, and the diagnostic accuracy increased from 43.9% for DM to 68.4% for DBT; for both parameters, the difference between the two techniques was statistically significant. These results are consistent with prior studies. Data on the differences in the detection rate and diagnostic accuracy between DBT and US have not been published. Furthermore, in our study, we show that the detection rate of US in patients with non-calcified DCIS was ranked higher than DBT (Fig. 1), and the difference was statistically significant. The diagnostic accuracy of US in patients with non-calcified DCIS was ranked slightly lower than DBT, but this difference was not statistically significant. Using US, 25 of 98 patients with non-calcified DCIS (25.5%) were diagnosed as BI-RADS 4A, with differences in the diagnosis compared with DBT (12.2%). Moon et al. reported that the most typical manifestation of DCIS observed by US was a dilated duct with low echo nodules, and since a dilated duct with tubercles is a common sonographic feature in intraductal papilloma, the lesions were difficult to identify. Consequently, non-calcified DCIS is often wrongly diagnosed as BI-RADS 4A and the diagnostic accuracy of US was ranked slightly lower than that of DBT. In our study, three of the patients with non-calcified DCIS were diagnosed as BI-RADS 3 by US, two of the three patients had masses with an irregular shape and circumscribed margins, while one patient had dilated ducts. All three patients were diagnosed correctly as BI-RADS 4 classifications by both DM and DBT. Therefore, the combination of the three techniques was beneficial for the diagnosis of patients with non-calcified DCIS.

In our study, 80 patients (81.6%) were classified as having dense breasts. The detection rates of DBT, DM, and

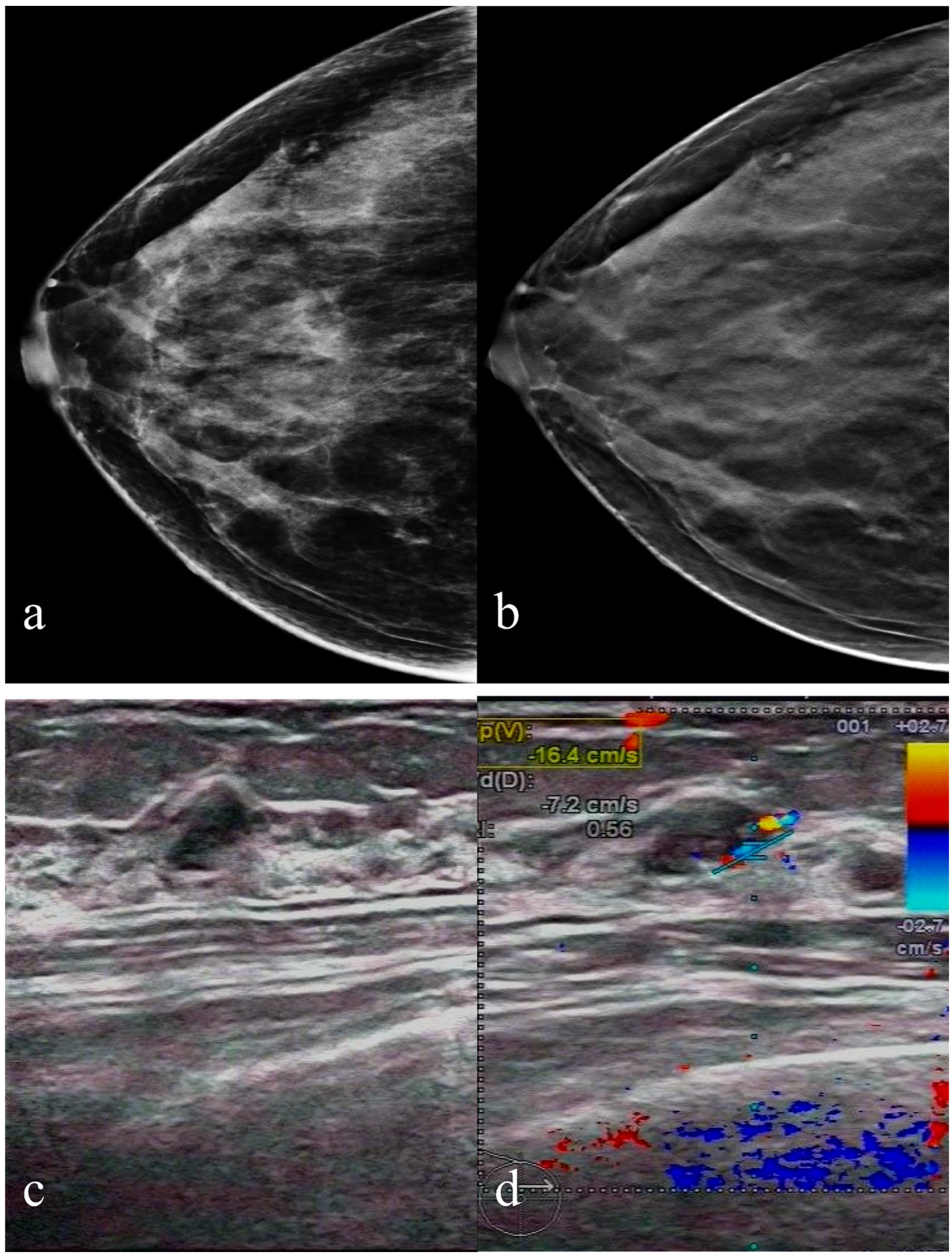

Fig. 1 Mammography and ultrasonography images in a 38-year-old woman with ductal carcinoma in situ in the *right* breast. **a** Craniocaudal DM image. **b** Craniocaudal DBT image. **c** US image. **d** US blood flow image. The lesion was not detected by any of the readers on DM and DBT (**b**). But on US (**c**, **d**), the lesion was detected with irregular shape, abundant blood flow, and the orientation of the mass was not oriented parallel to the skin. Reader scores for the study were 4A for US

US in patients with non-calcified DCIS in dense breasts were 81.2, 63.8, and 95.0%, respectively, and pairwise comparisons among the three techniques showed statistically significant differences. The diagnostic accuracy of US and DBT were significantly higher than that of DM in patients with dense breasts. These results show that DBT can reduce anatomic noise from overlying tissues and thus improve breast cancer detection compared to DM, a finding consistent with the previous reports [3, 10, 11]. US also has a high sensitivity for diagnosis of masses, especially in dense breasts [12]. However, in our study, although the diagnostic accuracy of DBT was slightly higher than that of US in patients with dense breasts, the difference was not statistically significant. Our results highlight the importance of DBT in the diagnosis of DCIS. For fatty breasts, the detection rate and diagnostic accuracy of the three techniques did not differ significantly.

In our study, the detection rate of DBT for spicules of the mass margin was superior to DM [13] (Figs. 2, 3). Furthermore, the imaging findings in patients with non-calcified DCIS were evaluated by DBT. On DBT, most patients with non-calcified DCIS presented with mass lesions with an irregular shape, indistinct margin, and isodensity. The focal asymmetry and architectural distortion lack distinct borders contain interspersed fat and are consequently difficult to diagnose. In our study, focal asymmetry was observed in 26 patients, architectural distortion in 11 patients, and 5 of 37 patients were diagnosed as BI-RADS 3 by DBT, whereas further sonographic examination ultimately revealed DCIS (Fig. 4). These results demonstrate the importance of further examination when imaging shows focal asymmetry and architectural distortion.

On US, most patients with non-calcified DCIS presented with a hypoechoic mass. The common findings of the masses included an irregular shape, indistinct margin, and a paralleled orientation. These findings were consistent with the report by Moon [14]. In our study, architectural distortion and hypoechoic areas were noted in 16 patients. Prediction of the benign and malignant lesions was difficult, and consequently, additional mammography and MRI were necessary to establish the diagnosis. In addition, the irregular shape of DCIS observed by US was higher than by DBT, but the round shape and spiculated margin were more visible in DBT than US.

Our study had several limitations. First, our study was retrospective; therefore, the results were not representative of the entire clinical environment and the patients were not randomized. In our study, some patients were examined by targeted ultrasonography guided by mammography to look for lesions, which may have increased the detection rate of non-calcified DCIS. Since our US review was retrospective, abnormalities on US may not have been documented.

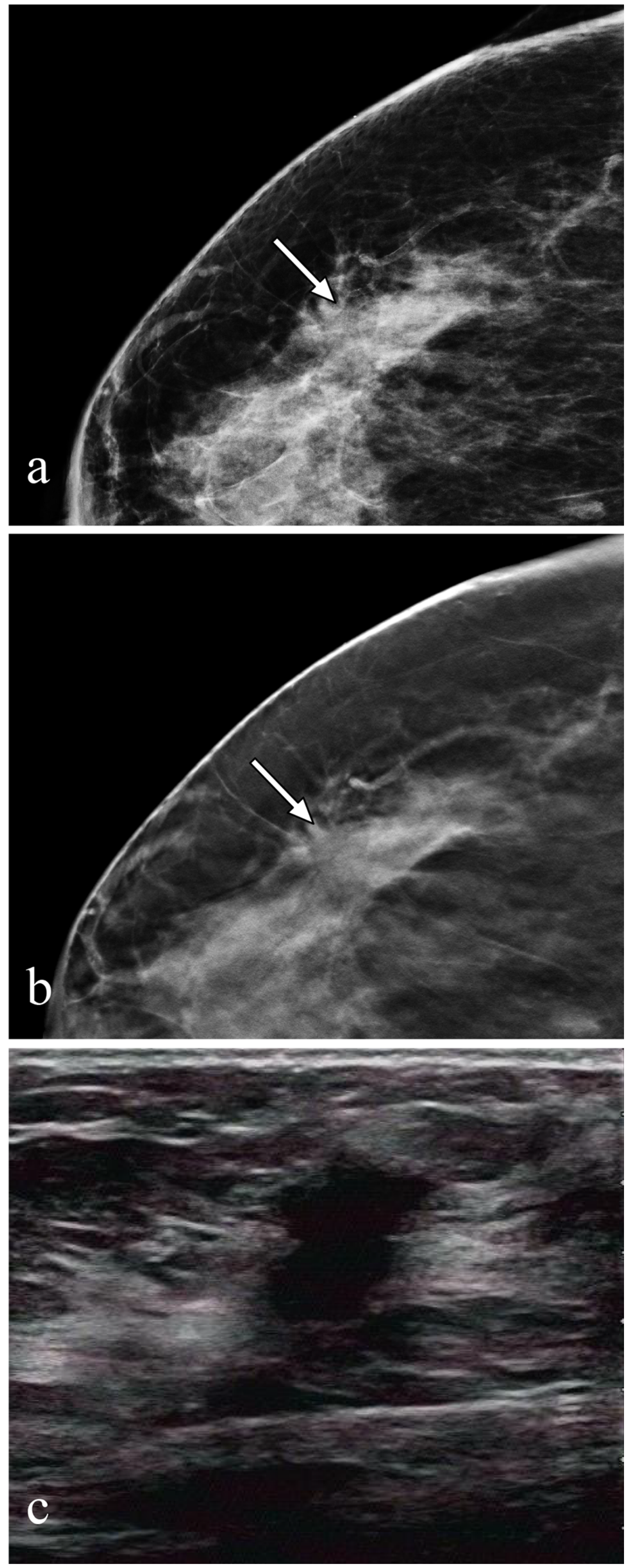

Fig. 2 Craniocaudal and ultrasonography images in a 62-year-old woman with ductal carcinoma in situ with micro-invasive in the *right* breast. **a** DM image. **b** DBT image. **c** US image. The spiculated mass *margins* are better shown in **b** than in **a**. US **c** showed a typically malignant findings

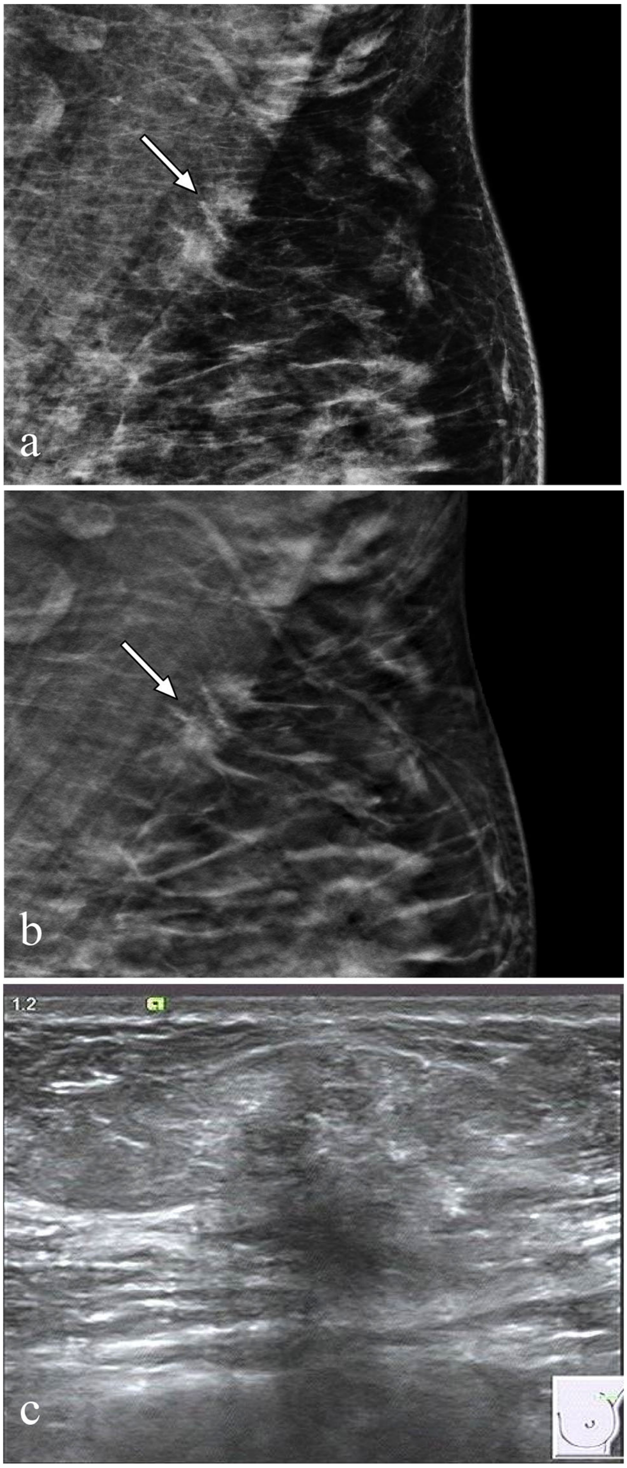

Fig. 3 Mediolateral oblique and ultrasonography images in a 43-year-old woman with ductal carcinoma in situ in the *left* breast. **a** DM image. **b** DBT image. **c** US image. The spiculated mass *margins* are better shown in **b** than in **a**. US **c** showed a typically malignant findings

Second, the experts analyzed the diagnoses by the three techniques in the case of abnormal patients, but which breast was involved was not known. The diagnostic

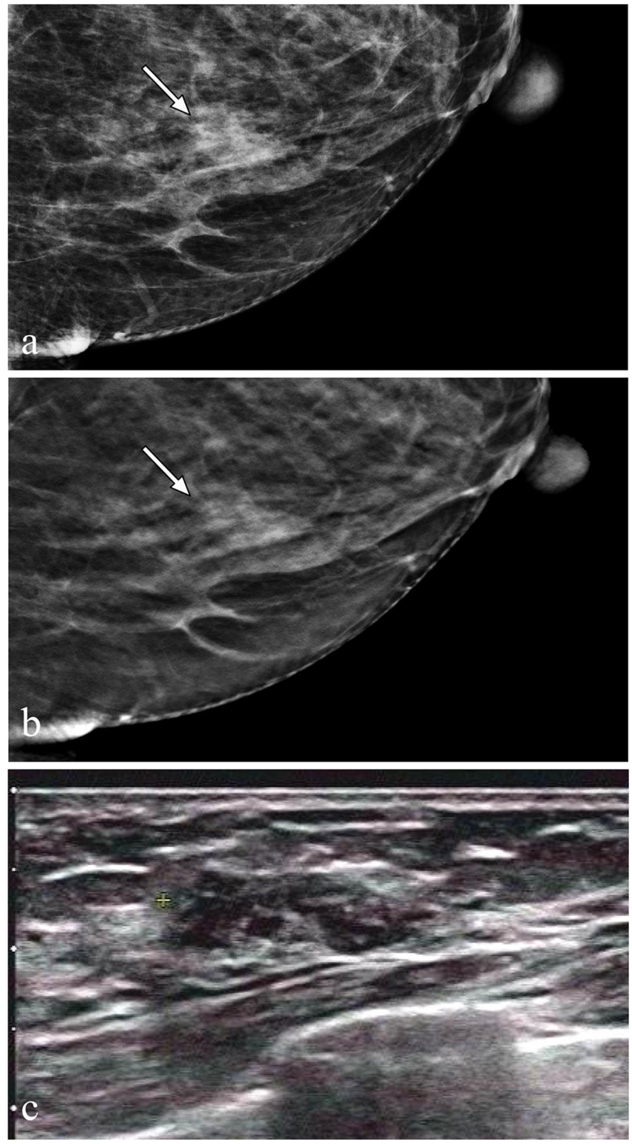

Fig. 4 Mammography and ultrasonography images in a 59-year-old woman with ductal carcinoma in situ in the *left* breast. **a** Mediolateral oblique DM image. **b** Mediolateral oblique DBT image. **c** US image. The lesion was detected by DBT and DM (**b**, **a**, *arrow*) in which the fibroglandular was considered for the diagnosis and the reader scores were 3. But on US **c**, reader scores for the study were 4A

accuracy of DM and DBT was likely to be higher than normally observed. Third, all the patients were collected from our PACS system and all the experts came from our hospital. Therefore, our study may not be directly generalizable to a multi-institutional study.

Conclusion

Overall, the results of this study show a superior detection rate and diagnostic accuracy with DBT and US than with DM in all patients and in those with dense breasts. The detection rate of DBT was lower than that of US in all patients and in the group with dense breasts. The diagnostic accuracy of DBT was slightly higher than US in all cases and in dense breasts, but the difference was not statistically significant. Therefore, DBT has extensive application value, especially in Asian females with dense breasts. Imaging findings in patients with non-calcified DCIS were relatively non-specific. We believe that understanding of the three techniques would help reduce the omission diagnostic rate and the false-negative rate for non-calcified DCIS.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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