ORIGINAL ARTICLE

Comparison of Diagnostic Performance between MRI and Mammogram with Ultrasound in Surveillance for Local Recurrent Breast Cancer after BCT

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Objective: To compare the diagnostic performance of breast magnetic resonance imaging (MRI) and mammography with ultrasonography for detection of local recurrent breast cancer among female patients with post-breast conserving therapy (BCT).

Materials and Methods: The authors retrospectively enrolled 190 post-BCT female patients who underwent post-operative surveillance by breast MRI and mammography with ultrasonography at King Chulalongkorn Memorial Hospital between January 1, 2008 and July 1, 2019. Two radiologists reviewed the images from the two surveillance modalities, independently. The information including radiological and histopathological data were blinded during the review process. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were then estimated to reflect the diagnostic performance of the two modalities for detection of local recurrent breast cancer.

Results: Of the 190 patients, 52 (27.4%) were diagnosed as local recurrent breast cancer. Sensitivity, specificity, PPV, and NPV were 98.1%, 92%, 82.3%, 99.2%, respectively, for breast MRI, and 88.5%, 62.3%, 46.9%, 93.5%, respectively, for mammography with ultrasonography. The findings that could be better evaluated by breast MRI than by mammography with ultrasonography included post-operative change and benign mass ($p<0.001$), suspicious mass ($p<0.001$), and suspicious calcification ($p<0.003$).

Conclusion: Breast MRI is superior to mammography with ultrasonography for detection of local recurrent breast cancer after BCT. Furthermore, MRI can help clinicians avoid unnecessary biopsy and surgical interventions due to its ability to differentiate post-treatment change from local recurrent breast cancer.

Keywords: Breast conserving therapy; Magnetic resonance imaging; Breast MRI; Mammography with ultrasonography; Local recurrent breast cancer

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Breast conserving therapy (BCT) is a complete removal of breast tumor with concentric margin of surrounding healthy tissue, always followed by radiation therapy[1]. This therapy is performed for cosmetic reasons. In terms of the long-term survival, the BCT does not significantly differ from mastectomy in female patients with early breast cancer, so the BCT can be an alternative treatment for these patients[2]. Unfortunately, patients that underwent the BCT are still at greater risk of developing recurrent breast cancer compared to those who got mastectomy[2,3]. The cumulative incidence of recurrent breast cancer in ipsilateral and contralateral breast of those patients is 8.8% to 14.3% and 12%, respectively(4). Post-BCT surveillance is, therefore, necessary, as early detection during the follow-up period can improve the survival rate[5].

The National Comprehensive Cancer Network (NCCN) and the American Society for Clinical Oncology (ASCO) recommend post-BCT surveillance with mammography annually[6,7]. Although, there has been no established standard guideline in post BCT surveillance with magnetic resonance imaging (MRI), studies showed the benefits of MRI over the conventional imaging. For example, a Korean study showed better detection of recurrent breast cancer by MRI (100% sensitivity and 88% specificity) after the BCT among under-50-year-old female patients, compared to mammography alone (53% sensitivity and 96% specificity)[8]. Likewise, another study in South Korea demonstrated 18.1 additional recurrent breast cancer cases diagnosed by MRI per 1,000 under-50-year-old female

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patients with post-BCT and previously negative mammographic with ultrasonographic findings[4]. Furthermore, MRI is known to be more accurate than the conventional imaging in differentiating recurrent cancer from post-treatment changes at the post-BCT and radiation site[9,10]. With higher specificity of MRI, it is recommended to use the MRI in case of clinical or mammographic suspicions of breast cancer recurrence[11]. This is supported by a systematic review that also recommended the routine surveillance with MRI after BCT for patients with abnormal mammographic findings or those at high risk for local cancer recurrence[12].

To substantiate the above claims, further studies are still needed. The present study was then conducted to determine the diagnostic performance of breast MRI in comparison with mammography with ultrasonography for detection of local recurrent breast cancer after BCT, and to identify factors and imaging findings that can be better evaluated by breast MRI than by mammography with ultrasonography.

Materials and Methods

Study population

The authors used retrospectively collected data from the hospital systems of King Chulalongkorn Memorial Hospital including the hospital information system (HIS), the radiological information system (RIS), and the picture archiving and communication system (PACS). Three hundred forty-five post-BCT female patients who had undergone post-operative surveillance by breast MRI and mammography with ultrasonography at the hospital between January 1, 2008 and July 1, 2019 were identified. Of those patients, 155 were excluded including 41 because the interval between the two surveillance modalities exceeded three months, five for a lack of pathological information, six for known metastasis during the surveillance period, one for lactation or pregnancy, two for history of contralateral mastectomy, and 100 for lack of 24-month follow-up information. If several radiological images of the two surveillance modalities per patient were available, the images with their shortest interval were selected. Eventually, 190 post-BCT patients were included in the present study.

The present study was approved by the Institutional Review Board of the Faculty of Medicine, Chulalongkorn University and informed consent was waived (COA No.1135/2019, IRB No.450/61).

Imaging protocols

MRI was performed on a 1.5 Tesla system (Siemen Magnetom Espree, Siemens Medical Solutions, Erlangen, Germany) with 8-channel breast coil. The pre-contrast sequences include axial 3-dimensional high-resolution fat-suppressed T1-weighted, axial short T1 inversion recovery (STIR), axial T2-weighted images turbo-spin echo (TSE), and coronal T1-weighted sequences. After the contrast injection, dynamic contrast-enhanced MRI (DCE-MRI) was performed with axial 3-dimensional high-resolution T1-weighted, axial 3-dimensional fat-suppressed T1-weighted with and without subtraction, diffusion-weighted imaging (DWI), apparent diffusion coefficient (ADC), sagittal T2-weighted turbo spin echo, and coronal T2-weighted sequences.

The 3-dimensional mammography was performed using either Hologic Selenia Dimension or Hologic Lorad Selenia. Standard mediolateral and craniocaudal views were performed in every patient.

Whole breast ultrasonography was performed using either Philips L12-5, 45 Hz transducer or Supersonic L15-4, 55 Hz transducer.

Imaging analysis

Two radiologists with two and more than ten years of experience reviewed the images of MRI and mammography with ultrasonography separately on different days and independently. The two radiologists had only access to the images from the same modality for comparison. To prevent possible bias, all the patients' information, including radiological and histopathological data were blinded during the review process. A BIRADS score was given by the researchers to each radiological image using the American College of Radiology Breast Imaging Reporting and Data System (ACR-BIRADS). In case of disagreement between them, consensus was made. Those given BIRADS scores were then categorized into the following two groups, the radiological images with the BIRADS score of 0 to 2 were deemed 'negative images', whereas those with the score of 4 to 5 were deemed 'positive images'. The images with the BIRADS score of 3 were classified as negative images if they were radiologically stable for the 2-year follow-up with mammography with ultrasonography, and conversely, classified as positive images if the pathological results of ductal carcinoma in situ (DCIS) or invasive breast cancer were available.

Subsequently, all the study images were compared to the gold standards, which include the negative 2-year follow-up radiological images for the negative group, and the pathological results of DCIS and invasive breast cancer for the positive group. The images that were consistent with their gold standard were defined as either 'true negative' and 'true positive'. For instance, a negative radiological image that was confirmed by the negative follow-up radiological images for two years was considered as true negative. Inversely, if the images differed from their gold standard, they were defined as either 'false negative' or 'false positive' depending on the initial radiological image. For example, an initial positive radiological where its pathological result did not show findings of DCIS or invasive breast cancer was considered as false positive.

Statistical analysis

Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were estimated to reflect the diagnostic performance of the two modalities for detection of local recurrent breast cancer, using a 2-by-2 table containing true-positive, true-negative, false-positive, and false-negative values. The Kappa coefficient of mammography with ultrasonography and breast MRI were analyzed to assess agreement with the gold standard.

Characteristics of patients with and without recurrent breast cancer were compared using Fischer's exact test and independent t-test. To identify factors that resulted in better detection of local recurrent breast cancer by breast MRI as well as between the group of correct assessment by breast MRI and the other group of correct assessments by mammography with ultrasonography, Fischer's exact test and independent t-test were used to analyze each factor. Additionally, the authors performed the other univariate analysis to identify factors associated with higher accuracy of breast MRI.

The above-mentioned statistical analysis was performed using the IBM SPSS Statistics, version 23.0 (IBM Corp., Armonk, NY, USA). A p-value of less than 0.05 was considered statistically significant. Consistently, confidence intervals were shown as 95%.

Results

One hundred ninety eligible female patients underwent post-BCT surveillance with breast MRI and mammography with ultrasonography at King Chulalongkorn Memorial Hospital between January 1, 2008 and July 1, 2019. The average interval between those two surveillance modalities was 15.5 days. The majority of the patients were over 50 years of age. Consistently, the patients were diagnosed as primary breast cancer at the average age of 50.71 years. Other information including the treatments and the clinicopathological data of primary breast cancer are listed in Table 1.

Fifty-two out of 190 cases had local recurrence of breast cancer. The group of patients with a positive margin will be treated to ensure that there was no residual tumor before surveillance.

Table 1. Demographic data (n=190)

Characteristic	n=190
Age at cancer diagnosis (year); mean±SD	50.71±10.53
Age at time of surveillance	
<40 years	11 (5.8)
40 to 50 years	51 (26.8)
>50 years	128 (67.4)
Intra-operative radio therapy; n (%)	
Yes	9 (4.7)
No	160 (84.2)
Unknown	21 (11.1)
Mammographic breast density; n (%)	
Almost entire fatty	1 (0.5)
Scattered area of fibroglandular density	27 (14.2)
Heterogeneously dense	154 (81.1)
Extremely dense	8 (4.2)
Size of primary breast cancer (cm); mean±SD	1.95±1.09
Histopathological subtype; n (%)	
DCIS	31 (16.3)
Invasive ductal carcinoma	126 (66.3)
Invasive lobular carcinoma	10 (5.3)
Others	8 (4.2)
Unknown; n (%)	15 (7.9)
Tumor grading; n (%)	
Carcinoma in situ	27 (14.2)
Grade I	25 (13.2)
Grade II	48 (25.3)
Grade III	51 (26.8)
Unknown	39 (20.5)
Margin; n (%)	
Positive	31 (16.3)
Negative	131 (68.9)
Unknown	28 (14.7)
Lymphovascular invasion; n (%)	
Positive	30 (15.8)
Negative	129 (67.9)
Unknown	31 (16.3)

DCIS=ductal carcinoma in situ; SD=standard deviation

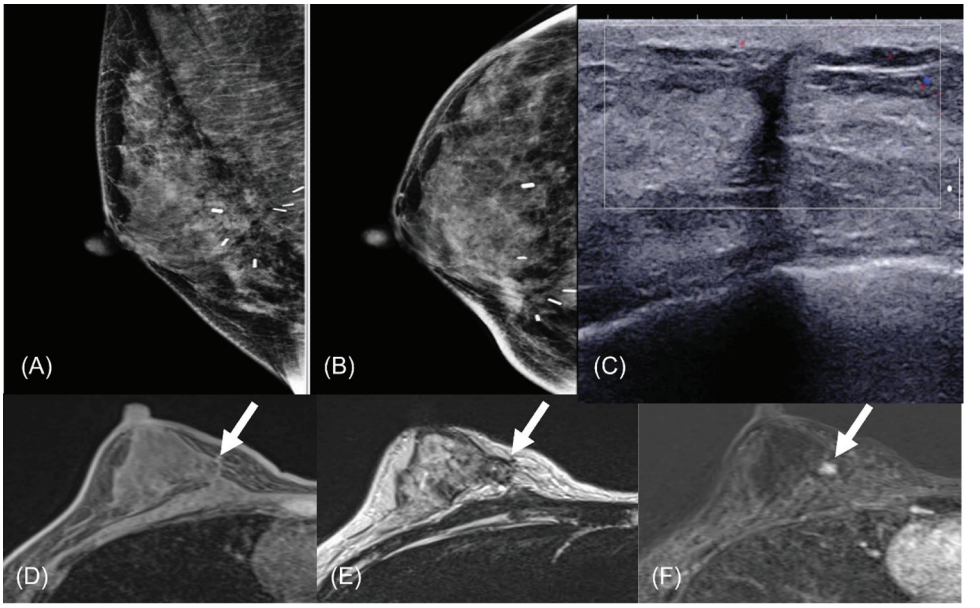

Figure 1. MRI true positive mammography and ultrasonography false negative: Mammography and ultrasonography show post-operative scar at right inner mid part (A-C). MRI reveals a 0.8×0.7-cm ill-defined mass at right inner mid part nearby the scar, showing isoSI in T1WI (D) and T2WI (E) with type I kinetic curve enhancement, suspicious for recurrent tumor. The pathological result from mastectomy was recurrent DCIS.

Of these patients, 50 out of 52 cases recurred in more than six months after the primary diagnosis. The patients' characteristics were not significantly different between the group of recurrence and the non-recurrence.

Of those 52 patients with local recurrent breast cancer, 51 recurrent cases were truly detected by breast MRI, while 46 cases were truly detected by mammography with ultrasonography as illustrated by Table 2. It was interesting to note that one case missed by breast MRI was able to be detected as suspicious calcification by mammography with ultrasonography. This case was pathologically confirmed, with the results of DCIS for the recurrence and invasive ductal carcinoma for the previous primary diagnosis. On the other hand, six false-negative cases with the radiological results of post-operative change by mammography with ultrasonography were detected by breast MRI as suspicious mass in five cases and as segmental ductal enhancement in the other one (Figure 1).

The 83 negative cases were truly identified (so-called true-negative) by all the radiological modalities, accounting for 60% of the non-recurrent patients, and 44 cases were falsely diagnosed as cancer recurrence by mammography with ultrasonography but correctly identified as true negative by breast MRI.

Other interesting cases were also observed. For example, 28 cases with suspicious mass detected by mammography with ultrasonography had MRI findings of post-operative change, benign mass, and normal as depicted in Figure 2. Similarly, 12 cases with suspicious calcification detected by mammography with ultrasonography had MRI results of post-operative change and normal. However, these patients were followed with radiological images and then their final diagnosis became benign dystrophic calcification. In contrast to the previous examples, there were 11 patients with false positive MRI results. Of those, one patient was correctly diagnosed as true negative by mammogram with ultrasonography. These findings were suspicious mass by breast MRI, but post-operative change or BIRADS 3 by mammography with ultrasonography. After being followed up for 24 months, the BIRADS score of 3 was eventually downgraded to BIRADS 2. These mentioned findings are depicted in Figure 3.

Table 2. Performance measures by surveillance modality

	MRI	Mammography with ultrasonography
True positive	51	46
True negative	127	86
False positive	11	52
False negative	1	6

MRI=magnetic resonance imaging

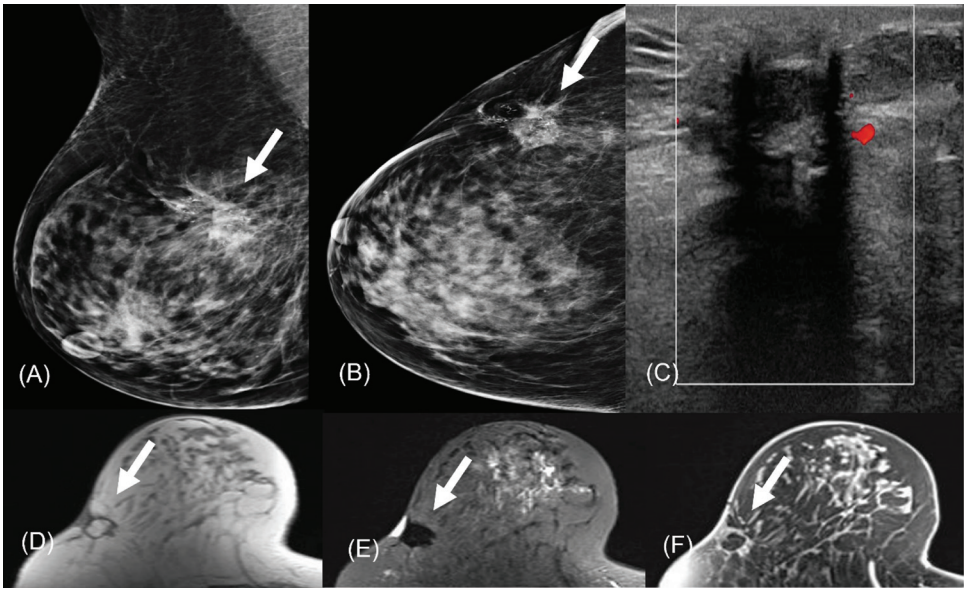

Figure 2. MRI true negative, mammography and ultrasonography false positive: Mammography with ultrasonography reveal a spiculated mass with internal calcification at the surgical bed in RUOQ (A-C), suspicious for abnormality. MRI shows that the suspicious mass is a fat containing mass without abnormal enhancement, compatible with fat necrosis (D-E).

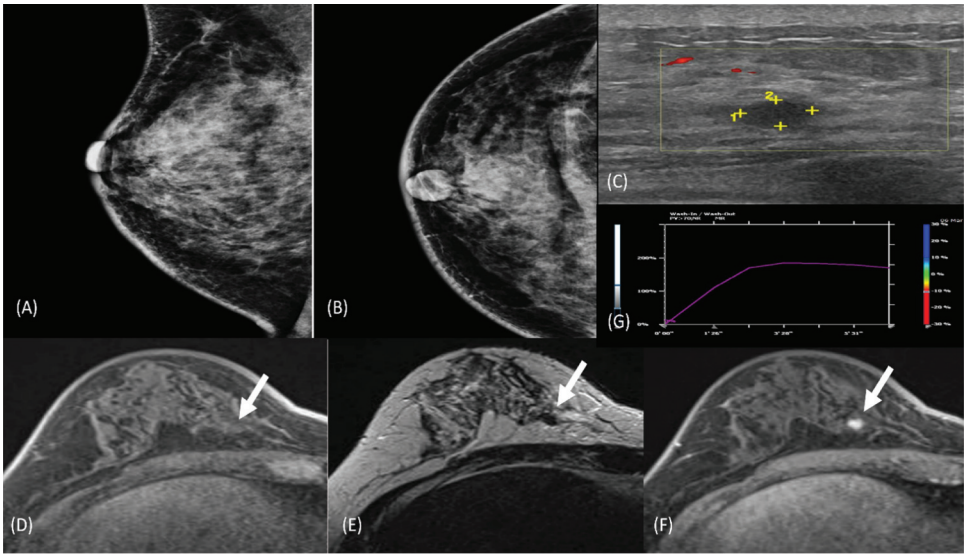

Figure 3. MRI false positive, mammography with ultrasonography false positive: Ultrasonography reveals a new 0.4×0.7-cm circumscribed hypoechoic nodule at RUIQ, suspicious for recurrent tumor (C). MRI reveals a 0.7×0.5-cm nodule at RUIQ, showing isoSI in T1WI (D), hypoSI in T2WI (E) with type II kinetic curve enhancement (F-G), suspicious for recurrent tumor. Pathological confirmation was benign and 24 months follow up imaging shows no recurrent tumor.

Looking at the performance measures, sensitivity and specificity of breast MRI was 98.1% (95% CI 89.7 to 100) and 92% (95% CI 86.2 to 96.0), respectively. Breast MRI was as statistically sensitive in detecting local recurrent breast cancer as mammography with ultrasonography at 88.5% (95% CI 76.6 to 95.6) and it was significantly more specific than mammography with ultrasonography at 62.3% (95% CI 53.7 to 70.4). PPV and NPV of breast MRI was 82.3% (95% CI 70.5 to 90.8) and 99.2% (95% CI 95.7 to 100), respectively, whereas the same values of mammography with ultrasonography was 46.9% (95% CI 36.8 to 57.3), 93.5% (95% CI 86.3 to 97.6), respectively.

Table 3. Univariate analysis for factors associated with better detection of local recurrent breast cancer by MRI

Variables	Recurrence detected only by MRI (n=6)	Recurrence detected evenly by MRI and mammography with ultrasonography (n=45)	p-value
Age at MRI; n (%)			
<40 years	1 (16.7)	1 (2.2)	0.224
40 to 50 years	2 (33.3)	13 (28.9)	1
>50 years	3 (50.0)	31 (68.9)	0.387
Age at cancer diagnosis; mean±SD	50.67±13.09	50.39±10.57	0.953
IORT; n (%)			
Yes	0 (0.0)	1 (2.2)	1
No	6 (100)	39 (86.7)	1
Chemotherapy; n (%)			
Yes	4 (66.7)	25 (55.6)	0.688
No	2 (33.3)	14 (31.1)	1
Hormonal therapy; n (%)			
Yes	5 (83.3)	27 (60.0)	0.392
No	1 (16.7)	10 (22.2)	1
Family history of breast cancer; n (%)			
Yes	0 (0.0)	2 (4.4)	1
No	1 (16.7)	1 (2.2)	0.224
BRCA mutation; n (%)			
Yes	0 (0.0)	0 (0.0)	N/A
No	1 (16.7)	1 (2.2)	0.224
Breast density; n (%)			
Almost entire fatty	0 (0.0)	0 (0.0)	N/A
Scattered area of fibroglandular density	1 (16.7)	8 (17.8)	1
Heterogeneously dense	5 (83.3)	36 (80.0)	1
Extremely dense	0 (0.0)	1 (2.2)	1
Site; n (%)			
Upper mid part	1 (16.7)	8 (17.8)	1
Upper outer quadrant	2 (33.3)	16 (35.6)	1
Outer mid part	0 (0.0)	2 (4.4)	1
Lower outer quadrant	0 (0.0)	3 (6.7)	1
Lower mid part	0 (0.0)	3 (6.7)	1
Lower inner quadrant	1 (16.7)	1 (2.2)	0.224
Inner mid part	0 (0.0)	9 (20.0)	0.575
Upper inner quadrant	2 (33.3)	3 (6.7)	0.099
Size (cm); mean±SD	1.54±1.19	1.75±0.93	0.652
Subtype; n (%)			
DCIS	1 (16.7)	9 (20.0)	1
IDC	3 (50.0)	27 (60.0)	0.680
ILC	2 (33.3)	2 (4.4)	0.063
Others	0 (0.0)	4 (8.9)	1
T stage; n (%)			
T0	0 (0.0)	1 (2.2)	1
T1	4 (66.7)	16 (35.6)	0.195
T2	1 (16.7)	15 (33.3)	0.651
T3	0 (0.0)	1 (2.2)	1
Tis	1 (16.7)	8 (17.8)	1

MRI=magnetic resonance imaging; IORT=intraoperative radiotherapy; DCIS=ductal carcinoma in situ; IDC=invasive ductal carcinoma; ILC=invasive lobular carcinoma; LVI=lymphovascular invasion; ER=estrogen receptor; PR=progesterone receptor; US=ultrasonography; MAM=mammography; SD=standard deviation; IQR=interquartile range

Table 3. (continued)

Variables	Recurrence detected only by MRI (n=6)	Recurrence detected evenly by MRI and mammography with ultrasonography (n=45)	p-value
N stage; n (%)			
Nx	1 (16.7)	2 (4.4)	0.319
N0	4 (66.7)	31 (68.9)	1
N1	0 (0.0)	5 (11.1)	1
N2	1 (16.7)	2 (4.4)	0.319
Grading; n (%)			
Carcinoma in situ	1 (16.7)	7 (15.6)	1
Grade I	0 (0.0)	9 (20.0)	0.575
Grade II	2 (33.3)	8 (17.8)	0.584
Grade III	1 (16.7)	13 (28.9)	1
Margin; n (%)			
Positive	1 (16.7)	8 (17.8)	1
Negative	5 (83.3)	31 (68.9)	0.657
LVI; n (%)			
Yes	0 (0.0)	7 (15.6)	0.578
No	6 (100)	30 (66.7)	0.162
ER; n (%)			
Positive	4 (66.7)	22 (48.9)	0.668
Negative	2 (33.3)	17 (37.8)	1
PR; n (%)			
Positive	2 (33.3)	19 (42.2)	1
Negative	4 (66.7)	20 (44.4)	0.402
HER2; n (%)			
Positive	2 (33.3)	16 (35.6)	1
Negative	4 (66.7)	21 (46.7)	0.419
MRI findings; n (%)			
Malignant mass	5 (83.3)	32 (71.1)	1
Segmental ductal enhancement	0 (0.0)	6 (13.3)	1
Non mass enhancement	1 (16.7)	6 (13.3)	1
US + MAM findings; n (%)			
Suspicious mass	0 (0.0)	26 (57.8)	0.01*
Suspicious mass with calcification	0 (0.0)	6 (13.3)	1
Focal thick duct	0 (0.0)	2 (4.4)	1
Architectural distortion	0 (0.0)	2 (4.4)	1
Pathologic lymph node	0 (0.0)	1 (2.2)	1
Normal	4 (66.7)	0 (0.0)	0
Post-operative change	2 (33.3)	0 (0.0)	0
Suspicious calcification	0 (0.0)	8 (17.8)	0.57
Interval MRI to MAM + US (days); median (IQR)	28.5 (24, 58)	16 (5, 28)	0.117

MRI=magnetic resonance imaging; IORT=intraoperative radiotherapy; DCIS=ductal carcinoma in situ; IDC=invasive ductal carcinoma; ILC=invasive lobular carcinoma; LVI=lymphovascular invasion; ER=estrogen receptor; PR=progesterone receptor; US=ultrasonography; MAM=mammography; SD=standard deviation; IQR=interquartile range

The Kappa coefficients indicate strong agreement between breast MRI and the gold standard tool (Kappa 0.85, agreement 93.7%) and weak agreement between mammography with ultrasonography and the gold standard tool (Kappa 0.4, agreement 69.5%).

According to the results of univariate analysis showed in Table 3, there were no independent variables that resulted in better detection of local recurrent breast cancer by breast MRI than by mammography with ultrasonography. Moreover, the authors performed the other univariate analysis to identify factors associated with higher accuracy

Table 4. Univariate analysis for factors associated with better diagnostic accuracy of MRI in all patients including recurrent and non-recurrent patients

Variables	Accuracy of MRI (n=50)	Accuracy of mammography with ultrasonography (n=128)	p-value
Age at MRI; n (%)			
<40 years	4 (8.0)	6 (4.7)	0.470
40 to 50 years	15 (30.0)	34 (26.6)	0.710
>50 years	31 (62.0)	88 (68.8)	0.479
Age at cancer diagnosis; mean±SD	49.78±9.25	51.2±11.15	0.426
IORT; n (%)			
Yes	3 (6.0)	5 (3.9)	0.688
No	43 (86.0)	109 (85.2)	1
Chemotherapy; n (%)			
Yes	35 (70.0)	74 (57.8)	0.171
No	11 (22.0)	38 (29.7)	0.354
Hormonal therapy; n (%)			
Yes	31 (62.0)	77 (60.2)	0.866
No	10 (20.0)	28 (21.9)	0.842
Family history of breast cancer; n (%)			
Yes	3 (6.0)	4 (3.1)	0.403
No	4 (8.0)	6 (4.7)	0.470
BRCA mutation; n (%)			
Yes	0 (0.0)	1 (0.8)	1
No	1 (2.0)	2 (1.6)	1
Breast density; n (%)			
Fatty	1 (2.0)	0 (0.0)	0.281
Scattered fibroglandular	4 (8.0)	22 (17.2)	0.157
Heterogeneous dense	43 (86.0)	101 (78.9)	0.396
Extremely dense	2 (4.0)	5 (3.9)	1
Site of primary cancer; n (%)			
Upper mid part	8 (16.0)	23 (18.0)	0.829
Upper outer quadrant	16 (32.0)	49 (38.3)	0.491
Outer mid part	4 (8.0)	14 (10.9)	0.783
Lower outer quadrant	4 (8.0)	5 (3.9)	0.271
Lower mid part	0 (0.0)	4 (3.1)	0.578
Lower inner quadrant	5 (10.0)	8 (6.3)	0.521
Inner mid part	2 (4.0)	3 (2.3)	0.621
Upper inner quadrant	7 (14.0)	17 (13.3)	1
Size of primary cancer; mean±SD	2.11±1.19	1.9±1.06	0.279
Subtype; n (%)			
DCIS	8 (16.0)	21 (16.4)	1
IDC	36 (72.0)	83 (64.8)	0.383
ILC	2 (4.0)	7 (5.5)	1
Others	1 (2.0)	7 (5.5)	0.445
T stage; n (%)			
T0	0 (0.0)	1 (0.8)	1
T1	17 (34.0)	53 (41.4)	0.397
T2	18 (36.0)	39 (30.5)	0.480
T3	1 (2.0)	3 (2.3)	1
Tis	8 (16.0)	20 (15.6)	1

MRI=magnetic resonance imaging; IORT=intraoperative radiotherapy; DCIS=ductal carcinoma in situ; IDC=invasive ductal carcinoma; ILC=invasive lobular carcinoma; LVI=lymphovascular invasion; ER=estrogen receptor; PR=progesterone receptor; US=ultrasonography; MAM=mammography; SD=standard deviation

Table 4. (continued)

Variables	Accuracy of MRI (n=50)	Accuracy of mammography with ultrasonography (n=128)	p-value
N stage; n (%)			
Nx	1 (2.0)	2 (1.6)	1
N0	36 (72.0)	85 (66.4)	0.592
N1	6 (12.0)	18 (14.1)	0.811
N2	3 (6.0)	9 (7.0)	1
N3	1 (2.0)	1 (0.8)	0.484
Grading; n (%)			
Carcinoma in situ	8 (16.0)	18 (14.1)	0.814
Grade I	7 (14.0)	17 (13.3)	1
Grade II	17 (34.0)	29 (22.7)	0.131
Grade III	9 (18.0)	39 (30.5)	0.132
Margin; n (%)			
Positive	9 (18.0)	22 (17.2)	1
Negative	36 (72.0)	87 (68.0)	0.719
LVI; n (%)			
Yes	8 (16.0)	20 (15.6)	1
No	35 (70.0)	88 (68.8)	1
ER; n (%)			
Positive	31 (62.0)	70 (54.7)	0.404
Negative	15 (30.0)	39 (30.5)	1
PR; n (%)			
Positive	27 (54.0)	59 (46.1)	0.405
Negative	19 (38.0)	50 (39.1)	1
HER2; n (%)			
Positive	16 (32.0)	38 (29.7)	0.856
Negative	27 (54.0)	68 (53.1)	1
MRI findings; n (%)			
Malignant mass	6 (12.0)	32 (25.0)	0.068
Benign mass	9 (18.0)	0 (0.0)	<0.001*
Segmental ductal enhancement	0 (0.0)	6 (4.7)	0.187
Non mass enhancement	2 (4.0)	6 (4.7)	1
Pathologic lymph node	0 (0.0)	1 (0.8)	1
Post-operative change	15 (30.0)	1 (0.8)	<0.001*
US + MAM findings; n (%)			
Suspicious mass	27 (54.0)	27 (21.1)	<0.001*
Suspicious mass with calcification	1 (2.0)	6 (4.7)	0.675
Focal thickened duct	3 (6.0)	2 (1.6)	0.136
Architectural distortion	1 (2.0)	2 (1.6)	1
Pathologic lymph node	0 (0.0)	1 (0.8)	1
Post-operative change	2 (4.0)	2 (1.6)	0.314
Suspicious calcification	12 (24.0)	9 (7.0)	0.003*
Time of recurrence; n (%)			
<6 months	0 (0.0)	2 (1.6)	1
>6 months	6 (12.0)	43 (33.6)	0.005*

MRI=magnetic resonance imaging; IORT=intraoperative radiotherapy; DCIS=ductal carcinoma in situ; IDC=invasive ductal carcinoma; ILC=invasive lobular carcinoma; LVI=lymphovascular invasion; ER=estrogen receptor; PR=progesterone receptor; US=ultrasonography; MAM=mammography; SD=standard deviation

of breast MRI. Table 4 shows the number of correct assessments consisting of true positive and true negative cases by the modalities. The factors that were more accurately evaluated by breast MRI than by mammography with ultrasonography include MRI findings of post-operative change and benign mass ($p<0.001$), mammographic findings of suspicious mass ($p<0.001$), and suspicious calcification ($p<0.003$).

Discussion

The results of the present study suggest that breast MRI has a better diagnostic performance for detecting local recurrent breast cancer in post-BCT patients than mammography with ultrasonography. More specifically, the relatively high specificity with high PPV of breast MRI contributes to correct diagnosis of breast cancer recurrence, by limiting the numbers of patients who could have been falsely diagnosed as cancer recurrence. A possible explanation could be the established strength of MRI in differentiating post-operative change like seroma, fat necrosis, hematoma, and benign dystrophic calcification from recurrent tumor in case of inconclusive mammographic and ultrasonographic findings[9]. This ability of MRI is consistent with the identified findings that were associated with the better diagnostic performance of breast MRI. Other previous study with a larger interval between the two modalities reported the different result that specificity of breast MRI was not significantly different from mammography[13].

Therefore, it can be concluded from the present study analysis that breast MRI is significantly more sensitive to detect local recurrent breast cancer than mammography with ultrasonography. This finding corresponds with the result of other prior studies[4,8,13].

The present study has the crucial clinical implication. With its high specificity, breast MRI can potentially prevent some patients from the wrong diagnosis of local recurrent breast cancer. Therefore, unnecessary following surgical procedures including tissue biopsy and their relevant costs can be avoided. Despite the aforementioned higher diagnostic accuracy of breast MRI, the current use of MRI in routine recurrent cancer surveillance is still limited because of its costs and availability. In the present study hospital, breast MRI costs almost five times more than mammography with ultrasonography. Physicians are encouraged to carefully consider the investigation alternatives by trading off between the direct cost of breast MRI and avoidable costs of unnecessary following procedures before making a decision. Nevertheless, mammography can still be helpful in detecting a certain condition of breast cancer. The present study highlighted the drawback of breast MRI where one case with early pre-invasive breast cancer or low-grade DCIS was missed by breast MRI but correctly identified by mammography with ultrasonography[15,16].

There are limitations to the present study. First, the authors' current practice might pose potential bias to the results. In the hospital, surveillance mammography with ultrasonography is initially used to detect local recurrent breast cancer. Once suspicious mammographic findings have been identified, patients with those findings will receive further investigations including breast MRI. In the present study, all the patients received both study modalities of which the mean interval was only 15.5 days. However, most of them received surveillance mammography with ultrasonography before breast MRI. This practice could, in turn, likely affect the estimates of sensitivity or specificity of breast MRI. Secondly, the data were collected and analyzed retrospectively, probably causing selection bias. Thirdly, the small sample size might affect the reliability of the results. Some findings are not statistically significant as they would otherwise be due to lack of power. Finally, other aspects such as cost-effectiveness, survival benefits from surveillance, and patient tolerability of the study modalities were not addressed in the present study. Further studies are therefore needed.

Conclusion

Breast MRI is superior to mammography with ultrasonography for detection of local recurrent breast cancer after BCT. Furthermore, breast MRI can help clinicians avoid unnecessary biopsy and surgical interventions due to its ability to differentiate post-treatment change from local recurrent breast cancer.

What is already known on this topic?

The NCCN and the ASCO recommend post-BCT surveillance with mammography annually. Although studies showed benefits of MRI over the conventional imaging, there has been no established standard guideline or recommendation in post-BCT surveillance with MRI.

What this study adds?

Breast MRI is superior to mammography with ultrasonography for detection of local recurrent breast

cancer after BCT. With its high specificity, breast MRI can potentially prevent some patients from the wrong diagnosis of local recurrent breast cancer and avoid unnecessary biopsy and surgical interventions.

Conflicts of interest

The authors declare no conflict of interest.

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