Comparison of Abbreviated Breast MRI vs Digital Breast Tomosynthesis for Breast Cancer Detection among Women with a History of Breast Cancer

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Rationale and Objectives: To compare the diagnostic performance of abbreviated breast MRI (AB-MRI) and digital breast tomosynthesis (DBT) in women with a personal history (PH) of breast cancer as a postoperative screening tool.

Materials and Methods: A total of 471 patients who completed both DBT and AB-MRI examinations were included in this study (median age, 54.5 years). The detected cancer characteristics were analyzed. The cancer detection rate (CDR), sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy, and area under the curve (AUC) were calculated by receiver operating characteristic (ROC) curve analysis.

Results: Eleven malignancies were diagnosed, and most of the detected cancers were stage I (7 of 11, 63.6%). Eight were invasive ductal carcinomas (IDC), and 3 were ductal carcinoma in situ (DCIS). Of the 11 recurrences, 6 malignancies were detected by DBT, and 11 were detected by AB-MRI. AB-MRI detected all 8 IDC and 3 DCIS lesions, and DBT detected 6 of 8 IDC lesions. The CDRs for DBT and AB-MRI screenings were 12.7 and 23.4 per 1,000 women, respectively. The sensitivity, specificity, PPV, NPV, and accuracy of DBT versus AB-MRI were 54.6% versus 100%, 97.6% versus 96.5%, 35.3% versus 40.7%, 98.9% versus 100%, and 96.6% versus 96.6%, respectively. AB-MRI showed a higher AUC value (0.983) than DBT (0.761) ($p = 0.0049$).

Conclusion: : AB-MRI showed an improved CDR, especially for invasive cancer. The diagnostic performance of AB-MRI was superior to that of DBT with high sensitivity and PPV without sacrificing specificity in women with a PH of breast cancer.

Key Words: Abbreviated breast MRI; Digital breast tomosynthesis; Breast neoplasm; Postoperative screening; Diagnostic performance.

Abbreviations: DBT digital breast tomosynthesis, **AB-MRI** abbreviated MRI, **CDR** cancer detection rate, **PPV** positive predictive value, **NPV** negative predictive value, **AUC** area under the curve, **ROC** receiver operating characteristic

INTRODUCTION

Surveillance after primary breast cancer treatment is important because there is an increased risk of secondary cancer in the treated breast and contralateral breast in this population (lifetime risk 15−20%) (1,2). Failed early detection of secondary cancer is associated with distant metastasis and increased mortality, resulting in a poor survival outcome (3,4). Current guidelines recommend mammography screening for surveillance after primary breast cancer treatment (5,6). However, post-surgical and post-radiation changes after breast cancer treatment may influence the diagnostic performance of mammography for the detection of tumor recurrence and can be an important reason for failed early diagnosis of secondary cancer (7,8), which suggests that

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TABLE 1. Characteristics of 471 Women with a PH of Breast Cancer Included in This Study

	Women without Recurrence (N = 460)	Women with Recurrence (N = 11)	*p*-value
Median age at diagnosis (years)	54.47(±9.19)	54.00(±10.39)	
Breast composition			0.8
- fatty	192 (97.5)	5 (2.5)	
- dense	268 (97.8)	6 (2.2)	
Operation type			0.89
-BCS	37 (97.4)	10 (2.6)	
-Mastectomy	423 (97.7)	1 (2.3)	
Pathology			0.14
- DCIS	63 (94.0)	4 (6.0)	
- IDC	337 (98.0)	7 (2.0)	
- ILC	18 (100.0)	0 (0.0)	
- Others	42 (100.0)	0 (0.0)	
TNM stage			0.26
- Stage 0	69 (94.5)	4 (5.5)	
- Stage I	205 (98.6)	4 (1.4)	
- Stage II	134 (97.8)	3 (2.2)	
- Stage III	52 (98.1)	1 (1.9)	
Subtype			0.05
- Lum A	252 (99.2)	2 (0.8)	
- Lum B	80 (94.1)	5 (5.9)	
- HER2 enriched	69 (97.2)	2 (2.8)	
- Triple negative	59 (96.7)	2 (3.3)	
HG			0.33
-Grade 1	85 (100.0)	0 (0.0)	
-Grade 2	189 (97.4)	5 (2.6)	
-Grade 3	104 (98.1)	2 (1.9)	
NG			0.36
-low	40 (100.0)	0 (0.0)	
-intermediate	200 (97.1)	6 (2.9)	
-high	202 (98.5)	3 (1.5)	

BCS, breast-conserving surgery; DCIS, ductal carcinoma in situ; HG, histologic grade; NG, nuclear grade; ER, estrogen receptor; PR, progesterone receptor; HER-2 human epidermal growth factor receptor; Lum A/B, luminal A/B; TN, triple negative.

Note: Numbers in parentheses are ranges.

other imaging modalities should be considered to supplement mammography. To overcome the limitations in mammography screening for postoperative surveillance, supplemental imaging methods, such as DBT, whole-breast ultrasonography, and breast MRI, are increasingly being used. Recently, the American College of Radiology (ACR) appropriateness criteria suggest that women with intermediate lifetime risk, including those with a personal history (PH) of breast cancer, may also benefit from supplemental screening, such as digital breast tomosynthesis (DBT) or breast magnetic resonance imaging (MRI) (9,10).

DBT provides acquisition of imaging slices through the breast tissue and enhances true lesion conspicuity, which leads to improved diagnostic performance compared to mammography in general screening (10–18). In the updated criteria, the ACR considers mammography or DBT to be a screening tool for imaging surveillance after primary breast cancer treatment (9,10). However, there have been very few data available on the benefit of DBT in the posttreatment surveillance setting (19–22).

Breast MRI is known for its high sensitivity for the detection of breast cancer (23). Although most guidelines did not support MRI due to insufficient evidence for or against it, recent studies support MRI screening in certain subsets of risk populations (24–28). MRI may be appropriate for intermediate-risk patients with a PH of breast cancer by the ACR appropriateness criteria (9). However, conventional breast MRI is difficult to use for screening purposes in large groups of women because it requires considerable time to acquire images and is expensive. Accordingly, abbreviated breast MRI (AB-MRI), which reduces the image acquisition time, has emerged as an alternative test (29). In particular, AB-MRI decreases the image acquisition time and interpretation time and has been shown to have similar diagnostic accuracy compared to conventional breast MRI (29,30). Thus, its use as a screening modality has been actively investigated at different risk levels of breast cancer.

Recently, a comparison of the screening performance between DBT and AB-MRI in women at average risk with dense breasts was published (31). However, to our knowledge, there are no published studies comparing the use of DBT and AB-MRI screening for women at elevated risk with a PH of breast cancer. Thus, the objective of this study was to compare the diagnostic performances of DBT and AB-MRI as postoperative surveillance tools.

MATERIALS AND METHODS

This retrospective study was approved by the Catholic Medical Center Office of the Human Research Protection Program (CMC-OHRP)/Institutional Review Board (Approval No. VC17RESI0107), and the requirement for informed consent was waived. Between October 2015 and October 2016, 577 AB-MRI and DBT exams were performed in 577 women with a PH of breast cancer. A total of 106 women were excluded because of DBT follow-up loss (N = 42), AB-MRI follow-up loss (N = 55), or distant metastatic disease (N = 9). A total of 471 women (median age, 54.5 years; age range, 23–89 years) with 471 AB-MRI and DBT scans were included in our study population. Recurrent cancers included ipsilateral breast tumor recurrence and metachronous breast cancer. Ipsilateral breast tumor recurrence was defined as secondary cancer in the ipsilat-

TABLE 2. Clinical and Imaging Characteristics of Recurrent Tumors in 11 Women with a History of Breast Cancer

		DBT			AB-MRI		Recurrent Breast Cancer							Primary Breast Cancer		
Pt. No	Age (years)	Parenchymal pattern	Lesion detection	Lesion type	Lesion detection	Lesion type	Location	Size	Histology	Node (+)	Stage	Grade	Subtypes	Histology	Stage	Subtype
41	56	a/b	-	-	+	NME	Contralateral	1.8	DCIS	-	TisN0	NG3	Lum A	DCIS	Stage 0	Lum A
163	58	c/d	-	-	+	Mass	Ipsilateral	1	IDC	-	T1N0	HG2	Lum A	IDC	Stage II	Lum A
175	50	c/d	-	-	+	Mass	Ipsilateral	0.6	IDC	-	T1N0	HG1	TN	IDC	Stage II	Lum B
201	50	c/d	-	-	+	NME	Ipsilateral	1	DCIS	-	TisN0	NG2	HER2(+)	DCIS	Stage 0	HER2(+)
251	56	a/b	+	Mass	+	Mass	Contralateral	0.8	IDC	-	T1N0	HG3	TN	IDC	Stage III	TN
263	75	a/b	+	Calcification	+	Mass	Ipsilateral	0.6	IDC	-	T1N0	HG3	Lum B	DCIS	Stage 0	Lum B
274	44	a/b	+	Mass	+	Mass	Ipsilateral	1.2	IDC	-	T1N0	HG2	Lum A	IDC	Stage I	Lum A
330	69	a/b	+	Mass	+	NME	Contralateral	1.1	IDC	+	T1N0	HG2	HER2(+)	IDC	Stage II	Lum B
346	44	c/d	_	-	+	NME	Ipsilateral	2	DCIS	-	TisN0	NG3	HER2(+)	DCIS	Stage 0	HER2(+)
389	58	c/d	+	Calcification	+	NME	Ipsilateral	1	IDC	-	T1N0	HG3	HER2(+)	IDC	Stage I	Lum B
455	39	c/d	+	Mass	+	Mass	Ipsilateral	1	IDC	-	T1N0	HG3	TN	IDC	Stage I	TN

IDC, invasive ductal carcinoma; DCIS, ductal carcinoma in situ; TN, triple negative; Lum A, luminal A; Lum B, luminal B; NME, nonmass enhancement

eral preserved breast or chest wall, and metachronous breast cancer was defined as a secondary cancer affecting the contralateral breast diagnosed after 6 months from the first cancer diagnosis.

In our institution, both DBT and AB-MRI have been implemented as part of routine posttreatment surveillance protocols since 2015. Patients who underwent surgery before 2015 underwent mammography and ultrasound for postoperative surveillance. However, from 2015, all patients who underwent surgery were recommended to undergo postoperative DBT and AB-MRI every 6 months for the first 2 years and annually thereafter. All mammographic imaging data were acquired by using a full-field digital mammography (DM) unit with integrated digital breast tomosynthesis (DBT) acquisition (Selenia Dimensions, Hologic) in the craniocaudal (CC) and mediolateral oblique (MLO) projections. For DBT examinations, we used the combination of the synthetic 2D images (SM, "c-view") reconstructed from a DBT data set plus DBT (SM+DBT) instead of the combination mode (DM+DBT) to minimize radiation exposure. AB-MRI examinations were performed along with DBT examinations on the same day or at approximately the same time (within 14 days). The median interval between the initial surgery for breast cancer and the first AB-MRI examination was 33.6 months (range, 6−187.5 months). AB-MRI was performed with the patient in the prone position using a 3 T MR scanner (MAGNETOM Verio, Siemens Medical Solutions, Erlangen, Germany) equipped with a dedicated surface breast coil. The AB-MRI protocols of our institution consisted of axial fat-suppressed, T2-weighted imaging (T2WI), pre- and postcontrast axial T1-weighted imaging (T1WI) before and 90 seconds after gadoterate meglumine injection (at 0.1 mmol per kilogram body weight, Dotarem; Guerbet, Anlnay-Sous-Bois, France), subtraction from postcontrast T1WI and reformatting with a maximum-intensity projection (MIP). The imaging parameters of the 3 T Verio scanner were as follows: (1) turbo spin echo T2WI: TR/TE, 3530/93 ms; slices, 34; FOV, 38 cm; matrix size, 576 × 403; NEX, 1; slice thickness, 4 mm; and (2) pre- and postcontrast T1WI with a flash 3D VIBE sequence: TR/TE, 3.8/1.4 ms; flip angle, 10°; slice thickness, 1.2 mm with no gap. The total acquisition times were 8.3 min, including T2WI and 2.8 min, excluding T2WI.

All imaging studies were retrospectively reviewed by two board-certified radiologists specializing in breast imaging, each with 17 years of experience in two steps: (1) sequential image review of SM+DBT, and then, (2) AB-MR. The AB-MR review was performed 4 weeks after the first step and in a random order different from that of the first step. Radiologists were blinded to the imaging findings of other modalities and clinical information, including pathologic results. BI-RADS category 4 or 5 was considered positive for malignancy, while categories 1 to 3 were considered negative. Any discrepancies were resolved by consensus.

Medical records were reviewed for final outcomes. We used a combination of tissue diagnosis or at least 2 years of follow-up as a reference standard. The cancer detection rate (CDR), sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy and area under the curve (AUC) were calculated by receiver operating characteristic (ROC) curve analysis of both AB-MR and DBT. The CDR was defined as the number of detected malignancies per 1,000 women. The diagnostic performances of AB-MRI and DBT examinations were evaluated and compared using ROC analyses. Clinicopathologic characteristics of the primary and secondary breast cancers were also obtained and compared

between women with and without tumor recurrence using Student's t-test or Fisher's exact test. Detected secondary cancer characteristics were analyzed.

All computations and statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA) and MedCalc ver. 16.1 (MedCalc software, Mariakerke, Belgium), and p-values < 0.05 indicated statistical significance.

RESULTS

Characteristics of the Study Population

The demographic details of the study population and the primary breast cancer characteristics of the 471 women with a PH of breast cancer are summarized in Table 1. A total of 11 recurrent tumors were diagnosed by AB-MRI and DBT overall. Women with and without tumor recurrence detected by AB-MRI and DBT differed significantly in HER-2 status and molecular subtype of primary breast cancer (Table 1). Women with a history of HER-2-positive primary breast cancer were frequently associated with tumor recurrence with a borderline significance ($p = 0.05$).

Characteristics of Secondary Cancer Detected on AB-MRI and DBT

The clinical and imaging findings of the detected malignancies are summarized in Table 2. A total of 23 lesions were biopsied, and 11 malignancies were diagnosed on AB-MRI and DBT. Eleven of 27 women (40.7%) with AB-MRI-positive findings were diagnosed with recurrent cancer, and 6 of 16 women (37.5%) with DBT-positive findings were diagnosed with recurrent cancer.

Most of the detected cancers were stage I (7 of 11, 63.6%). Eight were invasive ducal carcinomas (IDCs), and 3 were ductal carcinomas in situ (DCIS). The median size of invasive carcinoma was 0.9 cm (range, 0.6−1.2 cm), 50% (4 of 8) were high-grade tumors, and 87.5% (7 of 8) were node-negative.

AB-MRI detected all eleven recurrences, and the lesion types were as follows: mass ($n = 6$) and nonmass enhancement ($n = 5$). DBT detected 6 of 11 recurrences, and the lesion types were as follows: mass ($n = 4$) and calcifications ($n = 2$). AB-MRI detected all 8 IDC and 3 DCIS lesions, and DBT detected 6 of 8 IDC. AB-MRI detected more invasive cancer than DBT (100% vs. 75%) (Fig. 1, 2).

Cancer Detection Yield and Comparison of Diagnostic Performance Between AB-MRI and DBT

The CDR of AB-MRI screening was 23.4 per 1,000 women (11 of 471), and the CDR of DBT was 12.7 per 1,000 women (6 of 471). Thus, the additional CDR for AB-MRI was 10.7 per 1,000 women. A comparison of the diagnostic performance between AB-MRI and DBT is shown in Table 3, and the corresponding ROC curve analysis is shown in Figure 3. AB-MRI showed higher sensitivity and PPV than DBT (100% and 54.6% vs. 35.3% and 40.7%, respectively). The specificity, NPV, and accuracy were similar for AB-MRI and DBT. ROC curve analysis showed that the AUC was significantly higher for AB-MRI (0.983; 95% CI;

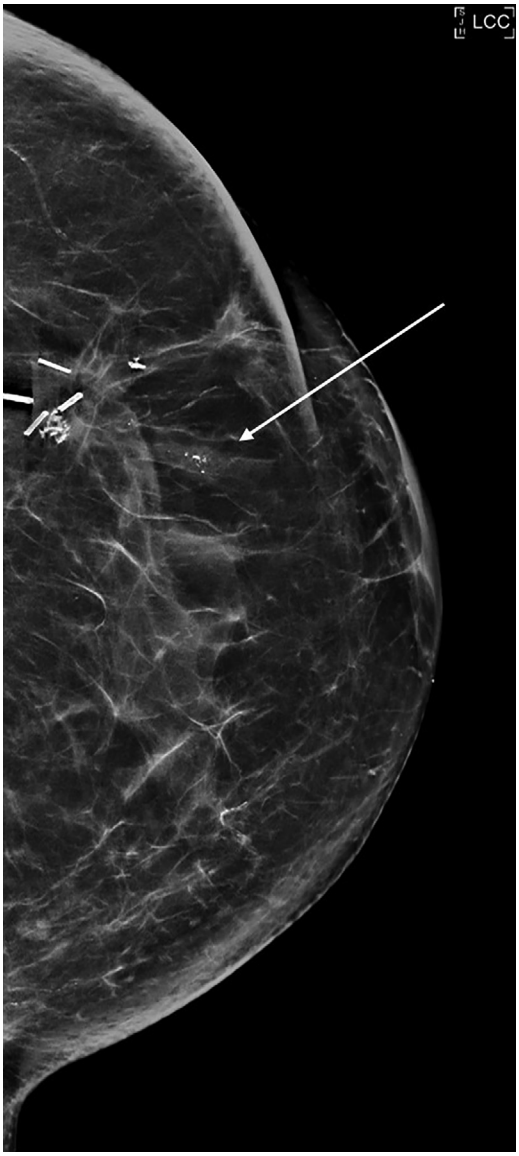

Fig. 1. A 75-year-old female patient with ipsilateral breast tumor recurrence detected 5 years after breast-conserving surgery. The patient who underwent breast-conserving surgery for left breast cancer (DCIS, stage 0, Lum B) underwent both DBT and AB-MRI for postoperative surveillance. (a) Craniocaudal DBT C-view showed a small mass with grouped microcalcifications (arrow) in the left breast. (b) AB-MRI showed an approximately 0.6 cm oval circumscribed enhancing mass (arrow) on a subtracted maximum-intensity projection (MIP) image. This lesion was confirmed to be IDC (0.6 cm, histologic grade 3, Lum B). (Color version of figure is available online.)

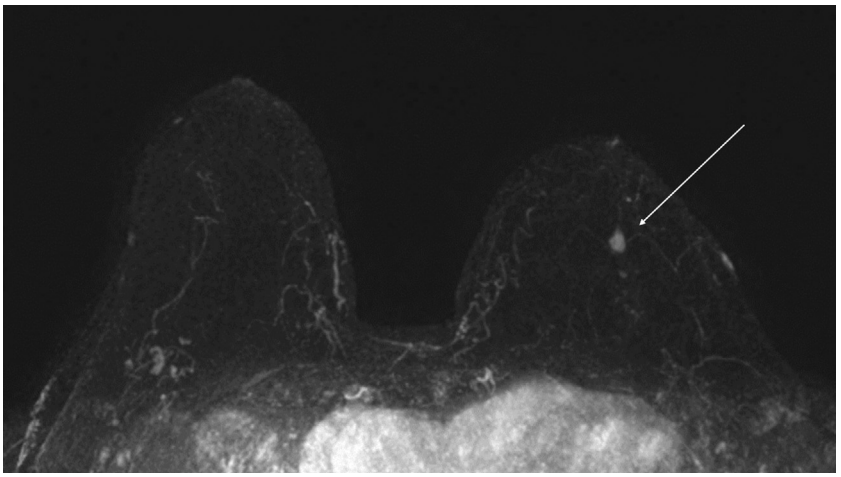

Fig. 1 Continued.

0.966−0.992) than for DBT (0.761, 95% CI; 0.720−0.799) ($p = 0.0049$) (Fig. 3).

DISCUSSION

In this retrospective study, we found that AB-MRI screening showed an improved CDR, especially for detecting invasive cancer, compared with DBT screening for women with a PH of breast cancer. The diagnostic performance was superior to that of DBT with high sensitivity and PPV without sacrificing specificity.

We observed that DBT showed an increased CDR and comparable diagnostic performance to DM in the posttreatment surveillance setting of breast cancer patients except for slightly lower sensitivity (1). In our study, DBT showed a CDR of 12.7 per 1,000 women, a sensitivity of 54.6%, a specificity of 97.6%, and a PPV for biopsy of 35.3%. To date, DBT has been shown to decrease the false-positive rate and increase the CDR in the general population, but its benefit in the posttreatment surveillance setting has not been well evaluated except for a few studies (19−22). Despite little data availability, previous studies showed that the addition of DBT to DM reduced the recall rate in women with a PH of breast cancer (19−22), which suggests that improved outcomes in the general screening setting can be extended to the posttreatment surveillance setting. Recently, the largest retrospective study about the performance of DBT compared with DM in breast cancer survivors was published (22). In this study, DBT led to a lower abnormal interpretation rate (5.8%) and higher specificity (95.0%) than DM but did not affect the CDR or interval cancer rate. The other diagnostic performance metrics and the detected tumor characteristics were also similar between the DM and DBT groups. In this study, screening DCE-MRI was performed in a portion of the cohort, and one-third of interval cancers were detected by MRI. These results suggest that DBT alone may not be the optimal tool for imaging surveillance in breast cancer survivors and that contrast imaging, such as DCE-MRI, may have a continued role as supplemental screening.

Breast MRI is known for its high sensitivity for detecting breast cancer. Current data support that a CDR of MRI screening in women with a PH of breast cancer is comparable to that in women with a genetic predisposition for breast cancer (32,33). For women with a PH of breast cancer, previous studies showed relatively consistent results that MRI offers considerably increased CDRs (ranging from 7 to 19 per 1,000 women), with a high sensitivity of 88.2−100% and high specificity of 89.9−98% (34−36). Our study demonstrated similar outcomes: AB-MRI (23.4 per 1000 women) was associated with a higher CDR than DBT (12.7 per 1000 women). The higher diagnostic performance of AB-MRI was associated with a high sensitivity of 100% but with specificity and PPV that was not significantly different from that of DBT. Regarding detected cancer characteristics, AB-MRI detected more invasive cancer (100% [8 of 8] vs. 75% [6 of 8]) and more high-grade DCIS (66.7%, [2 of 3]) (Fig. 2), which was consistent with previous results showing that MRI detects biologically significant cancers (37). In a recent study that compared the diagnostic performances of AB-MRI and DBT in average-risk women with dense breasts (30), AB-MRI was associated with a significantly higher CDR, especially in detecting invasive cancer, than DBT. AB-MRI detected all invasive cancers and 83.3% of DCIS, and DBT detected 41.1% of invasive cancers and 33.3% of DCIS. The CDR was 15.2 per 1,000 women for AB-MRI versus 6.2 per 1,000 women for DBT. AB-MRI showed a significantly higher sensitivity and slightly lower specificity than DBT (95.7% vs. 39.1% for sensitivity, 86.7% vs. 97.4% for specificity, respectively). Although this study was performed on a population with an average risk level, these results were

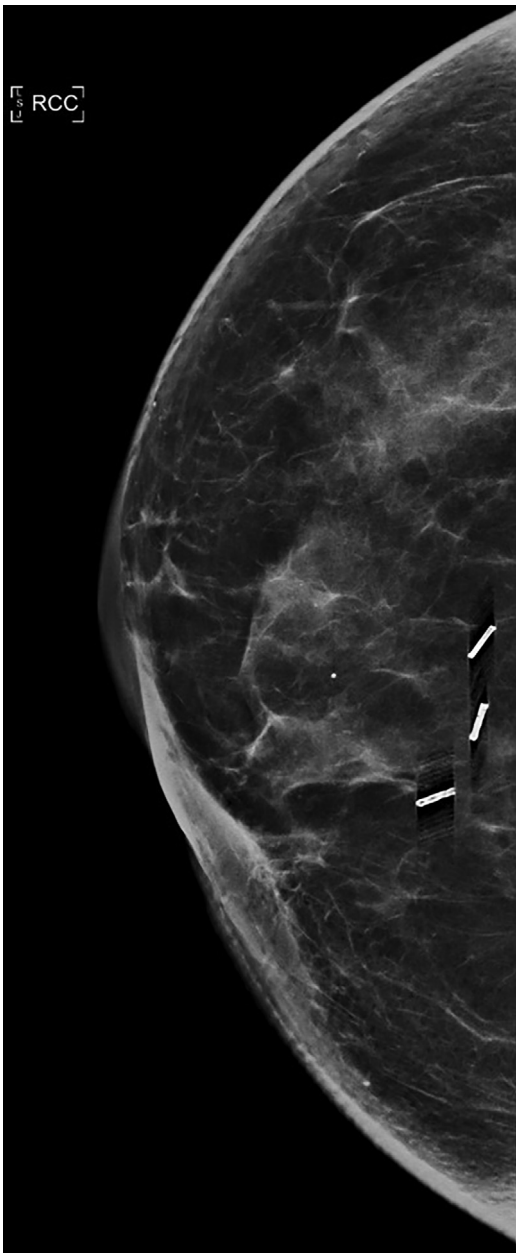

Fig. 2. A 44-year-old female patient with ipsilateral breast tumor recurrence detected 2 years after breast-conserving surgery. The patient who underwent breast-conserving surgery for right breast cancer (ductal carcinoma in situ, stage 0) underwent both DBT and AB-MRI for postoperative surveillance. (a) Craniocaudal DBT C-view showed postoperative changes and deformities of the right breast and no particular abnormalities. (b) AB-MRI showed focal nonmass enhancement (arrow) at 12:00 o'clock on a subtracted maximum-intensity projection (MIP) image. This lesion was confirmed to be DCIS (1.8 cm, nuclear grade 3). (Color version of figure is available online.)

consistent with ours, supporting that AB-MRI outperformed DBT with higher CDR and sensitivity and without sacrificing specificity.

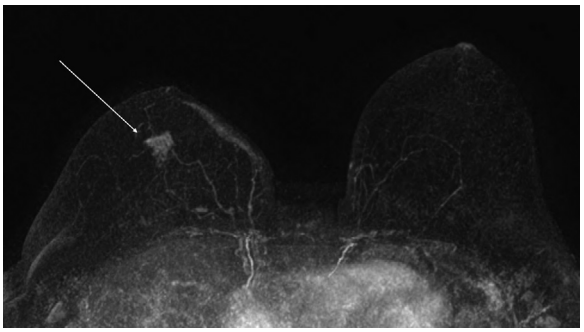

Fig. 2. Continued.

To our knowledge, this is the first investigation to compare the diagnostic performance of AB-MRI and DBT in women with a PH of breast cancer in the intermediate-risk group. Our study results suggest that AB-MRI could potentially be sufficient for posttreatment surveillance. However, larger prospective multi-institutional trials would be useful to further evaluate the findings in this study. However, if there are restrictions on the implementation of AB-MRI, such as claustrophobia or cost issues, or contraindications to performing AB-MRI, DBT may be helpful in such cases.

This study has several limitations. First, this was a retrospective study from a single institution. Selection bias may have affected the true CDR and diagnostic performance of AB-MRI, which might limit the generalizability of our results. Second, recurrent cancer may be missed because there are lesions that are found only as calcifications on DBT without any enhancing lesions on MRI. Nevertheless, in most cases, it can be supplemented because mammography is routinely performed for postoperative surveillance, and this is a limitation of MRI in general, not a limitation of this study. Third, the cost-effectiveness of AB-MRI relative to DBT was not evaluated. Although AB-MRI does not require additional equipment beyond what is used for conventional breast MRI, it is true that AB-MR requires the use of a contrast agent, is more expensive and time consuming than DBT and requires more equipment preparation. Fourth, we could not evaluate the appropriate interval or the survival benefit of AB-MRI screening in postoperative surveillance. Prospective, randomized, multicenter research should be continued for the broad application of AB-MRI screening in women with a PH of breast cancer.

Among women with a PH of breast cancer undergoing screening, AB-MRI, compared with DBT, showed an improved CDR, especially for invasive cancer. The diagnostic performance of AB-MRI was superior to that of DBT with high sensitivity and without sacrificing specificity in women with a PH of breast cancer. For postoperative surveillance, AB-MRI may be a useful screening modality in women with a PH of breast cancer.

TABLE 3. Comparison of Diagnostic Performance Characteristics Between DBT and AB-MRI for Detecting Tumor Recurrence

Modality	Cancer Detection Rate (per 1,000 women)	Sensitivity	Specificity	PPV	NPV	AUC	SE	Accuracy
DBT	12.7 (6 of 471)	54.55% (23.379, 83.251)	97.61% (95.762, 98.800)	35.29% (19.765, 54.706)	98.90% (98.156, 99.590)	0.761 (0.720, 0.799)	0.0788	96.60% (94.542, 98.046)
AB-MRI	23.4 (11 of 471)	100.00% (71.509, 100.000)	96.52% (94.413, 97.999)	40.74% (29.816, 52.665)	100.00%	0.983 (0.966, 0.992)	0.0043	96.60% (94.542, 98.046)

PPV, positive predictive value; NPV, negative predictive value; AUC, area under the ROC curve; SE, standard error

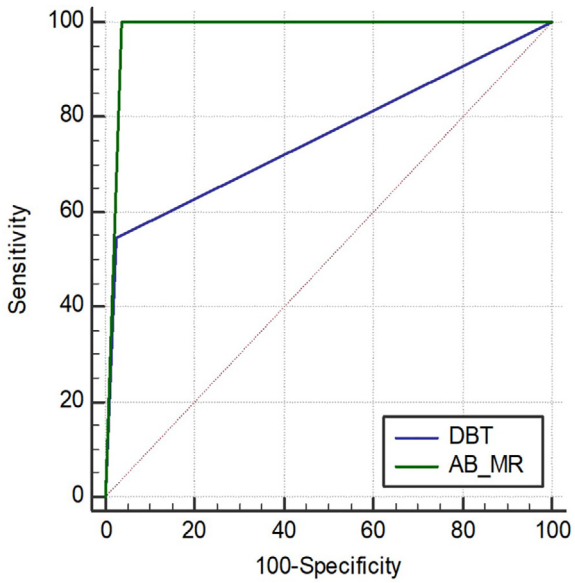

Fig. 3. Comparison receiver operating characteristic curve analysis between DBT and AB-MRI for detecting tumor recurrence. (Color version of figure is available online.)

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REFERENCES

1. Houssami N, Abraham LA, Miglioretti DL, et al. Accuracy and outcomes of screening mammography in women with a personal history of early-stage breast cancer. JAMA 2011; 305(8):790–799.
2. Weinstock C, Campassi C, Goloubeva O, et al. Breast magnetic resonance imaging (MRI) surveillance in breast cancer survivors. Springerplus 2015; 4:459.
3. Wapnir IL, Anderson SJ, Mamounas EP, et al. Prognosis after ipsilateral breast tumor recurrence and locoregional recurrences in five National Surgical Adjuvant Breast and Bowel Project node-positive adjuvant breast cancer trials. J Clin Oncol 2006; 24(13):2028–2037.
4. Lu WL, Jansen L, Post WJ, et al. Impact on survival of early detection of isolated breast recurrences after the primary treatment for breast cancer: a meta-analysis. Breast Cancer Res Treat 2009; 114(3):403–412.
5. Runowicz CD, Leach CR, Henry NL, et al. American Cancer Society/American Society of Clinical Oncology Breast Cancer Survivorship Care Guideline. J Clin Oncol 2016; 34(6):611–635.
6. Khatcheressian JL, Hurley P, Bantug E, et al. Breast cancer follow-up and management after primary treatment: American Society of Clinical Oncology clinical practice guideline update. J Clin Oncol 2013; 31(7):961–965.
7. Chansakul T, Lai KC, Slanetz PJ. The postconservation breast: part 1, Expected imaging findings. AJR Am J Roentgenol 2012; 198(2):321–330.
8. Peters ME, Fagerholm MI, Scanlan KA, et al. Mammographic evaluation of the postsurgical and irradiated breast. Radiographics 1988; 8(5):873–899.
9. Expert Panel on Breast I, Mainiero MB, Moy L, et al. ACR Appropriateness Criteria((R)) Breast Cancer Screening. J Am Coll Radiol 2017; 14(11S):S383–SS90.
10. Monticciolo DL, Newell MS, Moy L, et al. Breast cancer screening in women at higher-than-average risk: recommendations from the ACR. J Am Coll Radiol 2018; 15(3 Pt A):408–414.
11. Friedewald SM, Rafferty EA, Rose SL, et al. Breast cancer screening using tomosynthesis in combination with digital mammography. JAMA 2014; 311(24):2499–2507.
12. Zackrisson S, Lang K, Rosso A, et al. One-view breast tomosynthesis versus two-view mammography in the Malmo Breast Tomosynthesis Screening Trial (MBTST): a prospective, population-based, diagnostic accuracy study. Lancet Oncol 2018; 19(11):1493–1503.
13. Vedantham S, Karellas A, Vijayaraghavan GR, et al. Digital breast tomosynthesis: state of the art. Radiology 2015; 277(3):663–684.
14. Houssami N. Digital breast tomosynthesis (3D-mammography) screening: data and implications for population screening. Expert Rev Med Devices 2015; 12(4):377–379.
15. Houssami N, Skaane P. Overview of the evidence on digital breast tomosynthesis in breast cancer detection. Breast 2013; 22(2):101–108.
16. Ciatto S, Houssami N, Bernardi D, et al. Integration of 3D digital mammography with tomosynthesis for population breast-cancer screening (STORM): a prospective comparison study. Lancet Oncol 2013; 14(7):583–589.
17. Rose SL, Tidwell AL, Bujnoch LJ, et al. Implementation of breast tomosynthesis in a routine screening practice: an observational study. AJR Am J Roentgenol 2013; 200(6):1401–1408.
18. Skaane P, Bandos AI, Gullien R, et al. Comparison of digital mammography alone and digital mammography plus tomosynthesis in a population-based screening program. Radiology 2013; 267(1):47–56.
19. Sia J, Moodie K, Bressel M, et al. A prospective study comparing digital breast tomosynthesis with digital mammography in surveillance after breast cancer treatment. Eur J Cancer 2016; 61:122–127.
20. Yoon JH, Kim EK, Kim GR, et al. Comparing recall rates following implementation of digital breast tomosynthesis to synthetic 2D images and digital mammography on women with breast-conserving surgery. Eur Radiol 2020; 30(11):6072–6079.
21. Chikarmane SA, Cochon LR, Khorasani R, et al. Screening mammography performance metrics of 2D digital mammography versus digital breast tomosynthesis in women with a personal history of breast cancer. AJR Am J Roentgenol 2021; 217(3):587–594.
22. Bahl M, Mercaldo S, McCarthy AM, et al. Imaging surveillance of breast cancer survivors with digital mammography versus digital breast tomosynthesis. Radiology 2021; 298(2):308–316.
23. Mann RM, Cho N, Moy L. Breast MRI: state of the art. Radiology 2019; 292(3):520–536.
24. Berg WA, Zhang Z, Lehrer D, et al. Detection of breast cancer with addition of annual screening ultrasound or a single screening MRI to mammography in women with elevated breast cancer risk. JAMA 2012; 307(13):1394–1404.
25. Kriege M, Brekelmans CT, Boetes C, et al. Efficacy of MRI and mammography for breast-cancer screening in women with a familial or genetic predisposition. N Engl J Med 2004; 351(5):427–437.

26. Kuhl C, Weigel S, Schrading S, et al. Prospective multicenter cohort study to refine management recommendations for women at elevated familial risk of breast cancer: the EVA trial. J Clin Oncol 2010; 28(9):1450–1457.
27. Warner E, Plewes DB, Hill KA, et al. Surveillance of BRCA1 and BRCA2 mutation carriers with magnetic resonance imaging, ultrasound, mammography, and clinical breast examination. JAMA 2004; 292(11):1317–1325.
28. Kuhl CK, Strobel K, Bieling H, et al. Supplemental breast MR imaging screening of women with average risk of breast cancer. Radiology 2017; 283(2):361–370.
29. Kuhl CK. Abbreviated magnetic resonance imaging (MRI) for breast cancer screening: rationale, concept, and transfer to clinical practice. Annu Rev Med 2019; 70:501–519.
30. Kuhl CK, Schrading S, Strobel K, et al. Abbreviated breast magnetic resonance imaging (MRI): first postcontrast subtracted images and maximum-intensity projection-a novel approach to breast cancer screening with MRI. J Clin Oncol 2014; 32(22):2304–2310.
31. Comstock CE, Gatsonis C, Newstead GM, et al. Comparison of abbreviated breast MRI vs digital breast tomosynthesis for breast cancer detection among women with dense breasts undergoing screening. JAMA 2020; 323(8):746–756.
32. Lehman CD, Lee JM, DeMartini WB, et al. Screening MRI in women with a personal history of breast cancer. J Natl Cancer Inst 2016; 108(3).
33. Destounis S, Arieno A, Morgan R. Personal history of premenopausal breast cancer as a risk factor for referral to screening breast MRI. Acad Radiol 2016; 23(3):353–357.
34. Choi BH, Choi N, Kim MY, et al. Usefulness of abbreviated breast MRI screening for women with a history of breast cancer surgery. Breast Cancer Res Treat 2018; 167(2):495–502.
35. An YY, Kim SH, Kang BJ, et al. Feasibility of abbreviated magnetic resonance imaging (AB-MRI) screening in women with a personal history (PH) of breast cancer. PLoS One 2020; 15(3):e0230347.
36. Cho N, Han W, Han BK, et al. Breast cancer screening with mammography plus ultrasonography or magnetic resonance imaging in women 50 years or younger at diagnosis and treated with breast conservation therapy. JAMA Oncol 2017; 3(11):1495–1502.
37. Sung JS, Stamler S, Brooks J, et al. Breast cancers detected at screening MR imaging and mammography in patients at high risk: method of detection reflects tumor histopathologic results. Radiology 2016; 280 (3):716–722.