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Magnetic Resonance Imaging-Guided Breast Biopsy in Korea: A 10-Year Follow-Up Experience

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Conflict of Interest
The authors declare that they have no competing interests.

ABSTRACT

Purpose: To evaluate the accuracy of magnetic resonance imaging (MRI)-guided breast biopsy.
Methods: We retrospectively reviewed the clinical data of 111 consecutive patients referred for MRI-guided breast biopsy after mammography and breast ultrasound between May 2009 and April 2019. After excluding 37 patients without follow-up images (> 2 years), 74 patients (74 lesions) were finally included. We reviewed the histologic results of MRI-guided biopsy and subsequent surgery, post-biopsy management, and breast cancer development during follow-up. We investigated the false-negative rate, ductal carcinoma in situ (DCIS) underestimation, atypical ductal hyperplasia (ADH) underestimation rate, and technical failure rate of MRI-guided biopsy.
Results: Among 74 scheduled MRI-guided biopsies, six were canceled because biopsy was deemed unnecessary, while three failed due to technical difficulties (technical failure rate: 3/68, 4.4%). MRI-guided biopsy was performed in 65 patients, of which 18 patients were diagnosed with malignant lesions, 46 with benign lesions, and one with ADH bordering on DCIS. Subsequent surgery (n = 27) showed DCIS underestimation in three cases (3/7, 43%), ADH underestimation in two cases (1/2, 50%), as well as seven concordant benign and 11 concordant malignant lesions. The overall false-negative rate was 4.3% (2/46). Thirty-eight out of 48 benign lesions were followed-up (median period, 5.8 years; interquartile range, 4.1 years) without subsequent surgery. Thirty-seven concordant benign lesions were stable (n = 27) or disappeared (n = 10); however, the size of one discordant benign lesion increased on follow-up MRI and it was diagnosed as DCIS after 1 year.
Conclusion: MRI-guided biopsy is an accurate method for exclusion of malignancy with a very low false-negative rate.

Keywords: Biopsy; Breast neoplasms; Image-guided biopsy; Magnetic resonance imaging

INTRODUCTION

Breast magnetic resonance imaging (MRI) with dynamic contrast enhancement is the most sensitive method for detecting breast cancer [1]. Preoperative breast MRI can detect additional malignant lesions that are not found on mammography and ultrasound (US) in 10%–20% of patients with proven breast cancers [2,3]. In women at a high risk for breast

Author Contributions

Conceptualization: Ko EY; Data curation: Cha SY, Han BK, Ko ES, Choi JS, Lee JE; Formal analysis: Cha SY, Park KW; Investigation: Cha SY, Ko EY, Choi JS, Park KW; Project administration: Ko EY; Supervision: Ko EY, Han BK; Writing - original draft: Cha SY; Writing - review & editing: Ko EY.

cancer, more than half of the lesions are detected only on MRI [4]. When breast MRI is used for surveilling patients with a personal history of breast cancer, the detection rate of secondary malignancy with MRI alone is estimated to be 12.0% [5]. However, as breast MRI has limited specificity (67%–77%) owing to the overlapping of morphologic features and enhancement kinetics, pathologic confirmation with biopsy is essential. Therefore, MRI-guided breast biopsy is required in patients with lesions only seen on MRI [6].

In the past 10 years, as breast MRI has been increasingly used for preoperative imaging and screening after surgery, MRI-guided breast biopsy has also been increasingly performed for lesions detected only on MRI. However, to our knowledge, only few studies have investigated long-term follow-up results and case management based on the histologic results of MRI-guided breast biopsy.

Some studies have reported long-term follow-up results and case management in Western countries [7-9]. However, the prevalence of breast cancer and clinical practices before and after MRI-guided biopsy in Western countries are different from those in Korea; clinical practitioners in Western countries do not perform second-look US scans for lesions detected on MRI, unlike the clinical practitioners in Korea. Thus, it is necessary to evaluate follow-up data of Korean patients who underwent MRI-guided biopsy and corresponding management based on histologic outcomes. The only study on MRI-guided biopsy in Korea reported preliminary data in a small number of patients without a sufficient follow-up period [3].

This study aimed to assess the accuracy of MRI-guided breast biopsy, including the cancellation rate, technical failure rate, underestimation rate, and false negative rate in the Korean population.

METHODS

Our Institutional Review Board approved this study (IRB No. 2019-06-023-001) and waived the requirement for obtaining informed consent.

Patients

We retrospectively reviewed the clinical data and magnetic resonance images (MRI) of 111 consecutive patients who were referred for MRI-guided breast biopsy between May 2009 and April 2019. We excluded 37 patients who lacked follow-up images for more than 2 years. Thus, 74 patients (74 lesions) were included in this study. MRI was the only imaging modality used in 14 patients who received interstitial foreign body injections. All other patients underwent mammography and breast US scans before a breast MRI, and suspicious lesions detected on MRI tested negative on both mammography and US scans; re-evaluation of mammography and second-look US scans targeting the MRI-detected lesions were also negative.

MRI

Diagnostic breast MRI was performed using a 1.5-T Achieva scanner (Philips Medical Systems, Best, The Netherlands) and a 3.0-T Achieva scanner (Philips Medical Systems) with a dedicated bilateral phased-array breast coil, and the patients in the prone position. The MRI protocol consisted of axial turbo spin-echo T1-weighted and fat-suppressed T2-weighted sequences and a 3-dimensional (3D) dynamic contrast-enhanced sequence. Axial dynamic contrast-enhanced images were obtained with 1 pre-contrast and 6 post-

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contrast dynamic series. After a bolus injection (0.1 mmol/kg) of gadobutrol (Gadovist; Bayer Healthcare, Berlin, Germany) followed by a 10 mL saline flush, images were acquired starting at 30 seconds, 6 times per 60 seconds, with a gradient echo sequence (enhanced T1 high-resolution isotropic volume excitation). The parameters of the 1.5-T scanner were as follows: repetition time/echo time, 6.5/2.5 ms; 1.5 mm sections without gap; flip angle, 12°; matrix size, 376 × 374; and field of view, 32 × 32cm. The parameters of the 3.0-T scanner were as follows: repetition time/echo time, 4.6/2.3 ms; 1.5-mm sections with no gap; flip angle, 24°; matrix size, 512 × 512; and field of view, 32 × 32cm. For screening MRI, an abbreviated protocol was also used that consisted of axial turbo spin-echo T2-weighted imaging and axial dynamic contrast imaging of pre-contrast and first 2 post-contrast scans.

MRI-guided biopsy

One of two radiologists, with 11 and 18 years of experience in breast imaging, respectively, performed each MRI-guided biopsy. The patients were placed in the prone position, and biopsy was performed using the lateral approach with a breast biopsy-dedicated compression device of the grid-localizing system (Biopsy Positioning Device Model MR-BI-160, MRI Devices; GE Healthcare, Little Chalfont, UK). A vitamin E capsule was used as a fiducial marker. After pre-contrast sagittal T1-weighted 3D turbo field-echo sequence to confirm the lesion's location within the grid-localizing system, post-contrast images were obtained 1 min after injecting the contrast agent (0.1 mmol/kg bolus of gadobutrol (Gadovist; Bayer Healthcare Pharmaceuticals, Berlin, Germany)) and flushing with 10 mL of saline. The location of the lesion was calculated manually as follows: by counting the number of grid spaces between the fiducial marker and the lesion in the horizontal (dorsal-ventral, *x*) and vertical (cranial-caudal, *y*) directions; and counting the slice number, which was obtained using a 1-mm slice thickness between the fiducial marker and the lesion for depth (medial-lateral, *z*). We used a 9 G vacuum-assisted biopsy (VAB) device (Automated Tissue Excision and Collection Breast Biopsy System; Suros Surgical Systems, Indianapolis, IN, USA) to sample at least 6 specimens from each patient. Post-biopsy MRI was performed to determine if the lesions had been sampled correctly, and a clip was inserted when a small lesion was mostly removed during biopsy. When subsequent surgical excision was performed for the biopsied lesion, preoperative US-guided localization was used for clip localization or post-VAB changes within 1 week of the MRI-guided biopsy.

Management after MRI-guided biopsy

When MRI-guided biopsy was performed, the histologic results of VAB were correlated with the MRI findings of the radiologists who performed the biopsy procedure. All patients with malignant histologic results underwent surgery after preoperative localization of the biopsy site within 1 month. Patient with benign biopsy results in Breast Imaging Reporting and Data System (BI-RADS) 4C lesions and discordant benign results in BI-RADS 4B lesions were recommended to undergo re-biopsy with surgical excision.

For patients with concordant benign lesions that were equal to or less than the BI-RADS 4B category and high-risk lesions, further excisional biopsy or imaging follow-up was performed. If MRI-guided biopsy failed or was canceled, follow-up MRI was performed after 6 months using the screening breast MRI protocol.

Data analysis

We reviewed the results of MRI-guided VAB and recommended proper management as described above. When subsequent surgery was performed after biopsy, we compared the surgical pathology reports with the biopsy reports. We evaluated the ductal carcinoma in situ

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(DCIS) underestimation rate, atypical ductal hyperplasia (ADH) underestimation rate, and false negative rate. During follow-up, we reviewed the follow-up MR images and assessed changes in the lesions. For the canceled or failed MRI-guided VAB cases, follow-up MRI was reviewed, and the changes in the lesions were assessed to determine if such lesions were stable, enlarged, shrunk, or disappeared.

We also reviewed the medical records to evaluate the age of the patients at the time of biopsy, the reason for breast MRI examination, and follow-up results. Two observers with experience in breast imaging (10 and 18 years, respectively) retrospectively reviewed the MR images from which biopsy was recommended; they also analyzed the MRI findings to characterize the lesions (mass or non-mass enhancement, size or extent of the lesion, and BI-RADS category), and determined background parenchymal enhancement (BPE) by consensus. Thereafter, we compared the clinical characteristics and findings of the patients with benign and malignant lesions, which were diagnosed by MRI-guided biopsies, to determine the factors that differed between the 2 groups. We also compared the clinical and MRI findings of the cases in which biopsies were conducted and the cases in which biopsies were not conducted. Additionally, we investigated the canceled biopsy and technical failure rates.

For statistical analysis, continuous variables were analyzed using the Wilcoxon rank-sum test, and categorical variables using the χ^2 test or Fisher's exact test. Univariate logistic regression was used to identify factors significantly related to biopsy results and cancellation of biopsies. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).

RESULTS

Among the 74 patients (mean age, 45.5 years; range, 29–70 years) who were scheduled for MRI-guided biopsy, 39 had additional MRI-detected lesions on preoperative MRI for proven breast cancers, 35 had screening MRI-detected lesions, 21 underwent a screening MRI after an earlier breast cancer surgery, and 14 underwent a screening MRI for interstitial foreign body injections. A flowchart of the management and outcomes of the lesions after surgery or follow-up is shown in **Figure 1**.

MRI-guided biopsy was performed in 65 lesions, but was not performed in 9 lesions. The biopsied lesions were malignant in 19 cases (29.2%), which included 7 cases of DCIS, 9 cases of invasive ductal carcinoma (IDC), 1 case of sarcoma, and 1 case of lymphoma. One lesion was diagnosed as ADH bordering on DCIS. The other 46 lesions (70.8%) were diagnosed as benign, including 2 cases of ADH.

Subsequent surgery was performed in all cases with malignant results and eight cases with benign results, including one discordant ADH that was highly suspicious on MRI under BI-RADS category 4C after MRI-guided VAB. After surgery, biopsy-proven DCIS was upgraded to IDC in 43% (3/7) of the cases, and discordant ADH was confirmed as IDC (1/2, 50%) (**Figure 2**). In addition to the discordant ADH, one discordant benign lesion was also identified as IDC; therefore, the false negative rate was 4.3% (2/46). All other benign cases showed benign pathology after surgery. The other 38 benign lesions were followed-up with mammography and US scans or MRI (median period, 5.8 years; range, 2–11 years; interquartile range, 4.1 years); 37 concordant benign lesions, including 1 case of ADH, were found to be stable (n = 27) or to have disappeared (n = 10) (**Figure 3**).

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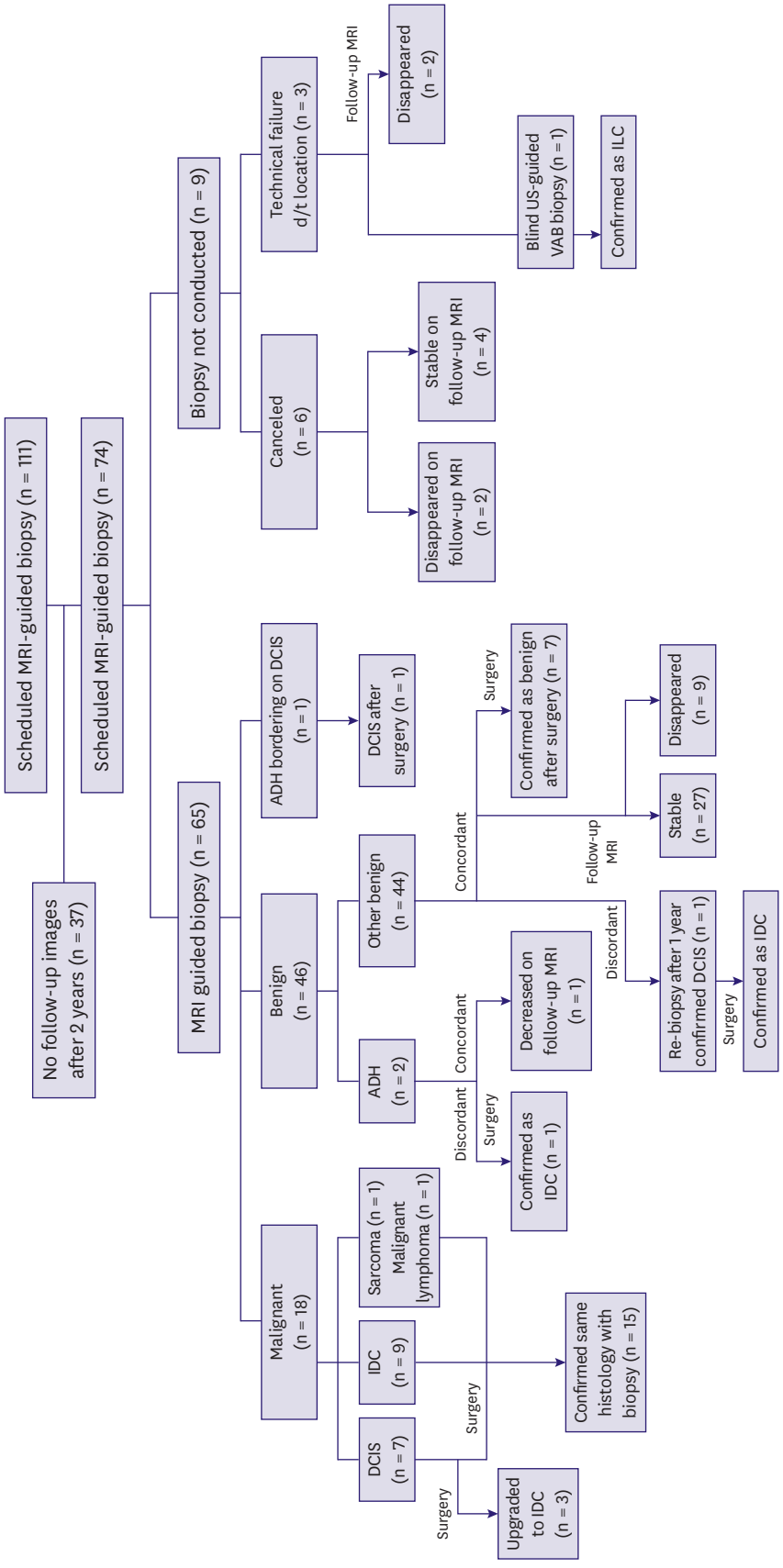

Figure 1. Flowchart of the management and outcomes of the lesions scheduled for MRI-guided biopsy.
MRI = magnetic resonance imaging; ADH = atypical ductal hyperplasia; DCIS = ductal carcinoma in situ; IDC = invasive ductal carcinoma; US = ultrasound; VAB = vacuum-assisted biopsy; ILC = invasive lobular carcinoma.

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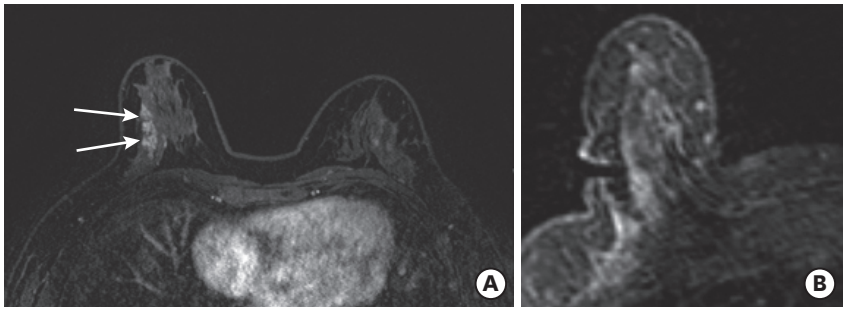

Figure 2. A 45-year-old woman with ADH underestimation case. (A) Axial T1-weighted fat-suppressed contrast-enhanced MR images show segmental heterogeneous non-mass enhancement in the right upper outer quadrant (arrows) on the early phase image. The lesion is categorized under BI-RADS 4C. (B) MRI-guided VAB was performed. The biopsy result was ADH. Subsequent surgery after US-guided wire localization for the area with post-VAB changes revealed IDC.
ADH = atypical ductal hyperplasia; MR = magnetic resonance; BI-RADS = Breast Imaging Reporting and Data System; MRI = magnetic resonance imaging; VAB = vacuum-assisted biopsy; US = ultrasound; VAB = vacuum-assisted biopsy; IDC = invasive ductal carcinoma.

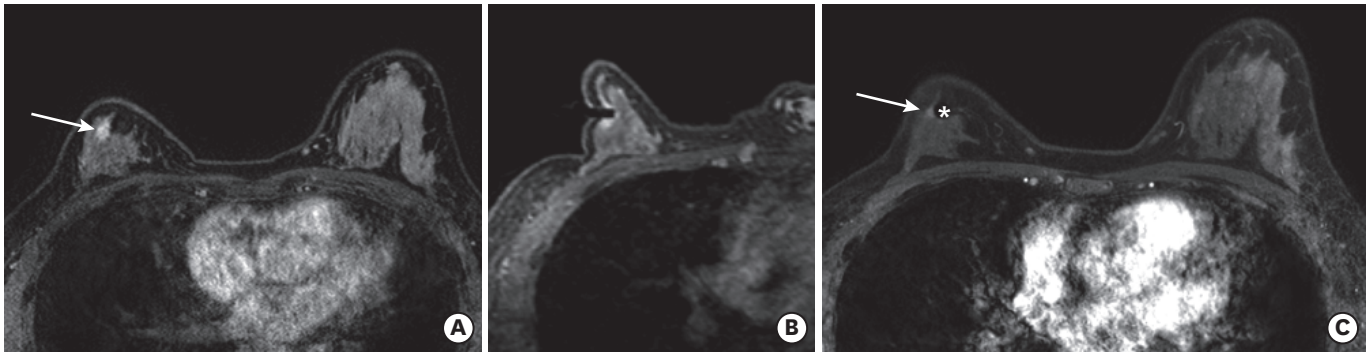

Figure 3. A 35-year-old premenopausal woman with a concordant benign result after a MRI-guided biopsy. (A) Axial T1-weighted fat-suppressed contrast-enhanced MR images obtained from the ipsilateral breast of the previous breast-conserving surgery show focal non-mass enhancement in the right upper outer quadrant on the early phase image (arrow). The lesion is categorized under BI-RADS 4B. (B) MRI-guided VAB was performed, and a marker was inserted at the biopsy site. The result was fibroadenomatoid mastopathy. (C) After 1 year, the lesion (arrow) around the marker (asterisk) decreased in size.
MRI = magnetic resonance imaging; MR = magnetic resonance; BI-RADS = Breast Imaging Reporting and Data System; VAB = vacuum-assisted biopsy.

One discordant benign case, which showed a 2.5 cm mild, persistent non-mass lesion around the surgical scar in a patient who had undergone previous breast-conserving surgery and radiation therapy 6 months ago, was assessed as BI-RADS 4A on the screening MRI. The lesion was incompletely biopsied owing to the surrounding dense fibrous scars and hardness of the breast due to radiation-related changes. Follow-up MRI was performed instead of immediate surgery because the patient refused another surgery, and the clinician considered the lesion as concordant benign. Follow-up MRI showed a gradual increase in the size of the lesion, and blind US-guided VAB of the MRI abnormality area confirmed the lesion as DCIS after 1 year (**Figure 4**). One ADH case was a 1.2 cm circumscribed mass with mild and persistent enhancement detected on the screening MRI. It was diagnosed as focal ADH, and the lesion was almost removed during MRI-guided VAB. This patient was followed up instead of receiving subsequent surgery, and follow-up MRI showed that the size of the lesion had decreased (2.5 years) without any treatment, including tamoxifen administration. One case of ADH bordering on DCIS was confirmed as DCIS after surgery.

In nine patients who did not undergo MRI-guided biopsy, biopsy was considered unnecessary and was not performed in six patients (canceled biopsy rate, 8.1%), because the lesions could not be visualized or were considered to be BPE at the time of biopsy. Four of them were stable on follow-up MRI for more than 2 years, and in two of them the lesions disappeared on follow-up MRI. The MRI-guided biopsies of three suspicious lesions failed due to

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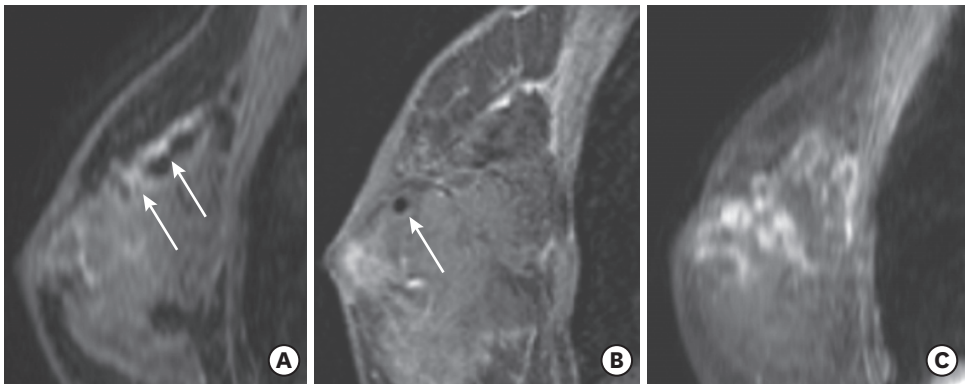

Figure 4. A 52-year-old woman with a discordant benign lesion on MRI-guided VAB but confirmed as IDC after surgery. (A) Sagittal T1-weighted fat-suppressed contrast-enhanced screening MR images after right breast-conversing surgery show linear non-mass enhancement in the right mid outer breast on the delayed phase image (arrows). The lesion is categorized under BI-RADS 4A. (B) On the day of biopsy, the biopsy needle was inserted into the inferior portion of the lesion (arrow) instead of its center, due to the surrounding dense fibrous scars and hardness of the breast owing to radiation-related changes. The biopsy was not thought to have been done properly, but the patient wanted a follow-up rather than immediate surgery. (C) follow-up MRI after 10 months, the lesion size increased. Surgery was done, and the lesion was revealed as an IDC.
MRI = magnetic resonance imaging; VAB = vacuum-assisted biopsy; IDC = invasive ductal carcinoma; MR = magnetic resonance; BI-RADS = Breast Imaging Reporting and Data System.

technical difficulties (technical failure rate: 3/68, 4.4%) of MRI-guided VAB; the lesions were not included within the biopsy field (compression grid) owing to excessive peripheral location in the axillary tail area (n = 2) and proximity to the chest wall (n = 1). One BI RADS 4B lesion in the axillary tail area underwent blind VAB for the topographic area of the MR abnormality, and the lesion was confirmed as invasive lobular carcinoma. The other two lesions disappeared on follow-up MRI (**Figure 5**). The patients that underwent MRI-guided VAB and those that did not undergo MRI-guided VAB did not show significant differences in any characteristics, including age, the reason for biopsy, morphologic features (mass or non-mass enhancement, maximum size), background parenchymal enhancement, and BI-RADS category of the lesion (**Table 1**).

Table 2 summarizes the characteristics of the two groups of cases that were finally proven to be malignant and benign. Among the 65 patients who underwent MRI-guided VAB, there was no significant difference in age, morphologic characteristics on MRI (mass or non-mass

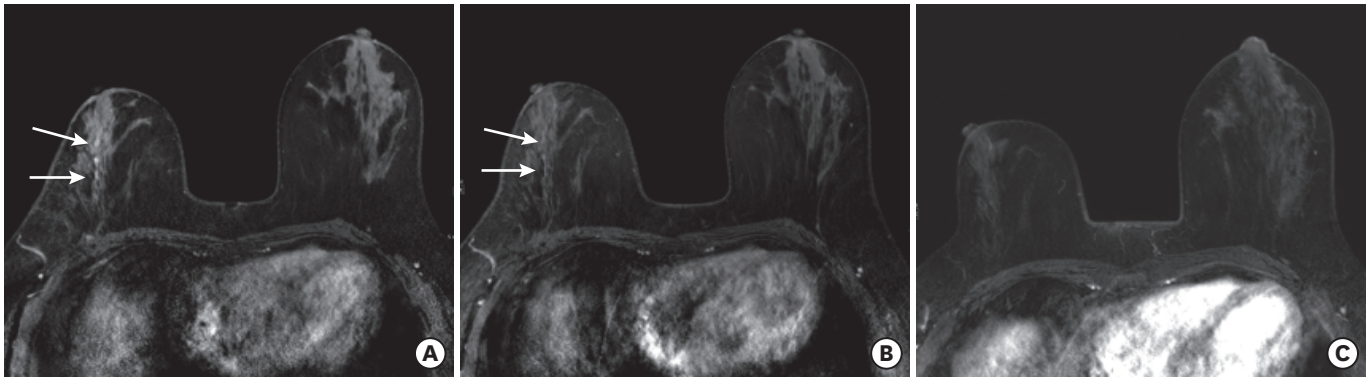

Figure 5. A 30-year-old premenopausal woman whose biopsy was canceled. (A) Axial T1-weighted fat-suppressed contrast-enhanced screening MR images after right breast-conversing surgery showed linear non-mass enhancement in the right mid outer breast on the delayed phase image (arrows). The lesion is categorized under BI-RADS 4A. (B) On the day of the scheduled biopsy (1.5 month after the previous MRI), the degree of enhancement of the lesion decreased, and the lesion became less prominent (arrows). Benign reactive enhancement along the duct as a post-operative change was considered, and the biopsy was then canceled. (C) On the follow-up MRI within 5 years, the lesion disappeared.
MR = magnetic resonance; BI-RADS = Breast Imaging Reporting and Data System; MRI = magnetic resonance imaging.

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Table 1. Characteristics of the conducted and not conducted MRI-guided biopsy groups

MRI feature	Biopsy conducted (n = 65)	Biopsy not conducted (n = 9)	Total (n = 74)	*p*-value
Age (yr)	45.6 ± 8.3	44.4 ± 13.9		0.614*
Size (cm)	1.9 ± 1.4	2.1 ± 3.0		0.147*
BPE				> 0.999†
Minimal	35 (53.9)	5 (55.6)	40 (54.1)	
Mild	16 (24.6)	2 (22.2)	18 (24.3)	
Moderate	6 (9.2)	1 (11.1)	7 (9.5)	
Severe	8 (12.3)	1 (11.1)	9 (12.2)	
Type				0.723†
Mass	35 (53.9)	6 (66.7)	41 (55.4)	
Non-mass	30 (46.2)	3 (33.3)	33 (44.6)	
BI-RADS category				0.629†
1	0	0	0	
2	0	0	0	
3	2 (3.1)	1 (11.1)	3 (4.1)	
4A	39 (60.0)	6 (66.7)	45 (60.8)	
4B	17 (26.2)	2 (22.2)	19 (25.7)	
4C	6 (9.2)	0	6 (8.1)	
5	1 (1.5)	0	1 (1.4)	
Reason for MRI				0.727†
Preoperative diagnosis	35 (53.9)	4 (44.4)	39 (52.7)	
Screening	30 (46.2)	5 (55.6)	35 (47.3)	

Values are presented as mean ± standard deviation or number (%).
MRI = magnetic resonance imaging; BPE = background parenchymal enhancement; BI-RADS = Breast Imaging Reporting and Data System.
*The *p*-values for age and size were calculated using the Wilcoxon rank-sum test. †The *p*-values for the other factors were calculated using Fisher's exact test.

Table 2. Characteristics of the MRI-guided biopsy-confirmed malignant and benign lesions

MRI feature	Malignant (n = 19)	Benign (n = 46)	Total (n = 65)	*p*-value
Age (yr)	46.6 ± 9.1	45.2 ± 8.1		0.410*
Size (cm)	2.0 ± 1.2	1.9 ± 1.5		0.483*
BPE				0.437
Minimal	12 (63.2)	23 (50.0)	35 (53.9)	
Mild	5 (26.3)	11 (23.9)	16 (24.6)	
Moderate	0	6 (13.0)	6 (9.2)	
Severe	2 (10.5)	6 (13.0)	8 (12.3)	
Type				0.900
Mass	10 (52.6)	25 (54.4)	35 (53.9)	
Non-mass	9 (47.4)	21 (45.7)	30 (46.2)	
BI-RADS category				0.001
1	0	0	0	
2	0	0	0	
3	0	2 (4.4)	2 (3.1)	
4A	5 (26.3)	34 (73.9)	39 (60.0)	
4B	9 (47.4)	8 (17.4)	17 (26.2)	
4C	4 (21.1)	2 (4.4)	6 (9.2)	
5	1 (5.3)	0	1 (1.5)	
Reason for MRI				0.004†
Preoperative diagnosis	5 (26.3)	30 (65.2)	35 (53.9)	
Screening	14 (73.7)	16 (34.8)	30 (46.2)	

Values are presented as mean ± standard deviation or number (%).
MRI = magnetic resonance imaging; BPE = background parenchymal enhancement; BI-RADS = Breast Imaging Reporting and Data System.
*The *p*-values for age and size were calculated using the Wilcoxon rank-sum test. †The *p*-values for the shape and reasons for MRI were calculated using the χ^2 test.

enhancement and maximum size), and BPE between the two groups. The BI-RADS category was the most important factor that was significantly different between the 2 groups (p = 0.0006), with the malignant group having a higher BI-RADS category than the benign group.

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The reason for MRI examination was also significantly different between the benign and malignant groups. Malignant results were more frequently found after biopsy of the lesions that were detected on the screening MRI after a personal history of breast cancer surgery than after biopsy of the lesions that were additionally detected on preoperative diagnostic MRI for staging-proven breast cancer (73.7% vs. 26.3%, $p = 0.0042$).

DISCUSSION

In this study, we assessed the accuracy of MRI-guided biopsies in a Korean population and found that the DCIS underestimation rate was 43% and the false negative rate was 4.3%. The cancellation rate, which is when the MRI-guided biopsy was canceled on the day of scheduled biopsy was 8.1%, but in 4.4% the MRI-guided bioscopies failed due to technical difficulties.

The false-negative rate in our study was very low, compared with the false-negative rate of 17.4%–23.2% in previous reports [8,9]; however, our DCIS underestimation rate was higher than that of other studies, which reported an approximately 20% DCIS underestimation rate [8]. Because we performed an MRI-directed second-look US scans for all lesions that were detected on MRI alone, large mass-forming lesions were filtered out in advance before MRI-guided biopsy, mainly leaving small non-mass lesions. This might have affected the higher percentage of DCIS underestimation. We usually obtained six samples along the clockwise direction using a 9G VAB device; however, increased sampling is desirable, especially in MRI-only detected small non-mass lesions, in order to decrease the DCIS underestimation.

In our study, scheduled MRI-guided breast biopsy was canceled owing to non-visualization of the target lesion or changed MRI findings suggesting BPE on the day of biopsy. The rate of biopsy cancellation was similar to that reported in previous studies from Western countries (8%–13%) [10-12]. Theories on the reason for biopsy cancellations include a hormonal false effect, which can affect vascularity and BPE, as well as focal inflammatory or fibrocystic changes that had dissipated at the time of the scheduled biopsy [10]. The cancellations in our institution can be explained by these theories, as the patients with suspicious MRI-detected lesions were mostly preoperative breast cancer patients or patients who had a personal history of breast cancer surgery. Considering that the median age of the Korean population with breast cancer is significantly lower than that of the Western population [13], and postoperative screening MRI was performed in patients with a personal history of breast cancer who were aged < 50 years [14], our study population included many premenopausal or perimenopausal patients and the canceled biopsies could be due to influences from hormonal false effects, focal inflammatory, or fibrocystic changes. Brennan et al. [10] reported that the factors associated with a significantly higher cancellation rate were marked and moderate BPE, and a lesion size of 1 cm. However, in our study, BPE and lesion size did not affect the cancellation rate. When we compared the canceled and non-canceled biopsy groups, both showed a similar incidence of minimal or mild BPE (78.5% vs. 77.8%) ($p > 0.9999$).

The rate of malignancy after MRI-guided breast biopsy was 27.7%, which is similar to the reported range of 18% to 60% [12,15-22] and the American College of Radiology (ACR) BI-RADS® Atlas 2013 benchmark of 20%–50% [23], suggesting adequate biopsy of the lesions at our institution. According to Myers et al. [8], the malignancy rate is associated with lesion size, washout kinetics, and marked background enhancement of the breast parenchyma. Han et al. [20] reported that the indication for MRI is a significant factor in that the cancer rate

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was higher in the diagnostic setting (i.e., with symptoms, imaging abnormality, or known cancer) than in the screening setting (i.e., in asymptomatic women). In our study, the BI-RADS category was the most significant factor that differed between the two groups, with the malignant group having a higher BI-RADS category. The reason for the MRI examination was also significantly different between the two groups. Malignant results were more frequently found in the lesions detected on screening MRI after previous breast cancer surgery than in those additionally detected on preoperative diagnostic breast MRI. The opposite results of our study compared to those of Han et al. [20] could be explained by the difference in the type of patients with screening MRI-detected lesions. More than half of the screening MRI patients in their study were asymptomatic women without a history of breast cancer, while all our patients had a history of breast cancer and a mean age of 44 years. Furthermore, BPE and lesion size did not differ between the malignant and benign groups. BPE was minimal or mild in 78.5% of all MRI-guided biopsy cases, 89.5% of the malignant cases and 73.9% of the benign cases (p = 0.4373). Based on our results, any suspicious findings, with an assessment of BI-RADS 4B or more detected upon screening MRI only, should be biopsied regardless of size or BPE.

Concordant benign biopsy results and canceled biopsy cases in our study showed no malignancy on follow-up MR images. Two discordant benign cases were immediately confirmed as malignancies as well as one year after biopsy. Previous studies recommend close follow-up MRI in cases of canceled biopsy or concordant benign lesions after MRI-guided biopsy [7,10,12]. The malignancy rate in cases of biopsy cancellation was 5.2%–12%, and the malignancy rate of lesions with concordant benign results was 2.3% in their study. However, Han et al. [20] and Liberman et al. [11] reported no cases of malignancy on follow-up, and up to 18 cases of canceled biopsy and 52 concordant benign lesions after MRI-guided biopsy. Our study also showed no cancer development during continuous follow-up after cancellation of biopsy or concordant benign results after biopsy, suggesting that close follow-up MRI might be unnecessary in this setting. In addition, as our study included lesions detected only on MRI, which were not found on mammography and US scans, as well as second-look US scans targeting the MRI-detected lesion, most included lesions were non-masses, sub-1 cm masses, or foci, which increased the false positive rates. Moreover, the convenience of MRI-guided biopsy compared to surgical excision might reduce the threshold for biopsy. As the population that underwent scheduled MRI-guided biopsy in Korea was different from that in previous studies, management after MRI-guided biopsy based on the results of previous studies might not yield the best outcomes for our patients. Our study data may be helpful for suggesting proper management and prognosis evaluation after MRI-guided breast biopsy in Korea.

Our study has some limitations. First, not all patients were followed up with breast MRI. Follow-up imaging was performed in patients with concordant benign results or in those who had a canceled needless biopsy. In 58% (19/33) of the patients, MRI was performed for follow-up imaging; however, the other patients were followed up with mammography and breast US scans, but not MRIs. Fortunately, most patients who underwent follow-up mammography and breast US scans underwent biopsy during the initial period of MRI-guided biopsy, and those who recently underwent MRI-guided biopsy were more likely to be followed-up with an MRI. Second, the number of cases was relatively small; thus, it is difficult to draw firm conclusions or suggest guidelines for clinical management. However, considering the number of MRI-guided biopsies performed in Korea, the analysis of 74 lesions with negative mammography and second-look US results, as well as the years' worth of follow-up images provide some evidence relevant to the management and follow-up of breast cancer patients in Korea.

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In conclusion, we suggest that the possibility of misdiagnosis of cancer after MRI-guided biopsy is extremely low in the Korean population with a low false-negative rate when a biopsy is canceled, or when a lesion is deemed concordant benign after a successful MRI-guided biopsy. Close follow-up MRIs might not be necessary in such cases.

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