Original Article

Implementation of abbreviated breast MRI in diagnostic and screening settings

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Abstract

Background: Abbreviated magnetic resonance imaging (MRI) includes fewer sequences than standard MRI, which could be utilized for breast cancer detection.

Purpose: To evaluate the diagnostic accuracy of abbreviated MRI protocol in screening and diagnostic settings.

Material and Methods: All women with screening and diagnostic (problem-solving and preoperative staging) MRI examination were recruited from 2017 to 2020. Two expert radiologists assessed designed abbreviated protocol (fat-saturated T1-weighted [T1W] pre-contrast and two first fat-saturated T1W post-contrast series with reconstruction of their subtraction) including maximum intensity projection (MIP) and then evaluated standard protocol of breast MRI. Associated findings, including axillary lymphadenopathy and invasion to nipple, skin, or pectoralis muscle were also evaluated. The concordance rate of abbreviated with standard protocol in screening and diagnostic settings were also compared, based on BI-RADS classification. Diagnostic accuracy, sensitivity, specificity, and positive and negative predictive value were calculated.

Results: A total of 108 (26.5%) of 408 patients (mean age = 43 ± 9 years) were classified as BI-RADS 4–5 and considered positive findings based on suspicious enhancement (mass or non-mass enhancement). Compared to standard protocol, abbreviated protocol revealed >98% accuracy in the diagnostic setting as well as 100% accuracy in the screening setting. Concordance rates in screening and diagnostic settings were 99.6% and 98.1%, respectively. There was no discordance between abbreviated and standard protocol in the evaluation of associated findings.

Conclusion: Abbreviated MRI protocol possesses substantial diagnostic accuracy in both screening and diagnostic settings. Additional information provided by standard protocol might not require for cancer detection.

Keywords
Breast neoplasms, magnetic resonance imaging, diagnostic test approval, abbreviated magnetic resonance imaging

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Introduction

Breast cancer is the leading cause of death from women's cancer in low-income countries while standing in second place in high-income countries (1). However, mammography screening has decreased breast cancer mortality and has improved the overall survival (1). Its breast cancer detection rate is believed to be approximately 30% in dense breasts compared to 80% in non-dense breasts; it should be noted that interval cancers are often more aggressive, node-positive, and triple-negative subtype (2).

In the latest guidelines of the American Society of Breast Cancer, magnetic resonance imaging (MRI) is adjunct to mammography in the screening of high-risk patients with a lifetime risk of 20%–25% or higher. The high-risk group includes some genetic mutations (e.g. BRCA1/2, TP53, PALPB2, ATM, CHECK2, CDHI, STK11, and PTEN) found in themselves or their first-degree relatives,

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patients with a history of chest irradiation before the age of 30 years, and those with with Li-Fraumeni, Cowden, or Bannayan-Riley-Ruvalcaba syndromes (3). Intermediate risk (lifetime risk of >15%–20%) patients comprised those with a personal history of breast cancer, dense breast at mammography, or history of high-risk lesions at previous biopsy (atypical lobular neoplasia, atypical ductal hyperplasia, or lobular carcinoma in situ). Ultrasound and digital breast tomosynthesis (DBT) are the most common modalities to improve the early detection rate of breast cancer, both of which have limitations. Ultrasound has a high false-positive rate, and DBT has no additional value in the extremely dense breast than digital mammography (4,5).

MRI, on the other hand, has exhibited the highest sensitivity in the detection of breast cancer (6). As MRI is mainly reserved for more advanced diagnostic approaches, including staging and lymph node detection, multiple sequences are integrated into the standard breast MRI protocol making it time-consuming and costly and limiting its application to high-risk patients (7). Abbreviated breast MRI, the emerging technology with the purpose of reducing time and cost of MRI screening, was first introduced in 2014 using one pre- and post-contrast T1 sequence and reconstructed maximum intensity projection (MIP) with or without T2-weighted images. Decreased acquisition time to about 3–8 min with preserved accuracy is reported (8). Since then, various abbreviated protocols with different acquisition times and costs have been proposed (9); yet the evidence was not robust enough to implement abbreviated MRI in routine screening settings in women at average and intermediate risk (10,11).

Although the abbreviated protocol has been mainly used as a screening tool in dense-breast patients with intermediate risk, including women with a history of breast cancer (12,13), its diagnostic value has not yet been investigated. Herein, the aim of the present study was to assess the accuracy of abbreviated and MIP protocols based on the standard protocol in a heterogeneous group of patients who were referred to our breast cancer institute, in detecting and staging breast cancer using the minimum required sequences and acquisition and interpretation time.

Material and Methods

Study design and participants

This retrospective study was reviewed and approved by the institutional review board and ethics committee of Imam Khomeini Hospital of Tehran University of Medical Sciences (IR.TUMS.IKHC.REC.1400.403). This study was conducted in our quaternary referral university hospital between 2017 and 2020. All individuals who underwent standard breast MRI protocol for screening or diagnostic purposes were included and studies with marked motion artifacts and patients who received neoadjuvant chemotherapy were excluded.

MRI acquisition protocol and interpretation

The study was performed with GE Discovery MR750 3T MRI scanner (GE Healthcare, Waukesha, WI, USA) with dedicated breast coil (multichannel coil 16-row). Details of sequences of both abbreviated and standard protocols are summarized in Table 1.

Using the sequential reading, two expert fellowship-trained radiologists, blinded to the clinical data, independently evaluated the MRI sequences. MIP images were first interpreted to make a decision based on BI-RADS category. Then, an abbreviated protocol using fat-saturated T1-weighted (T1W) pre-contrast and two first fat-saturated T1W post-contrast series and their coronal and sagittal reconstruction images were evaluated. Finally, standard protocol MRI images were interpreted. It should be mentioned that the readers made a decision and locked it in before moving to the next protocol so that they were not able to go back and change their decision. Inter-rater agreement (IRA) between two radiologists was recorded and determined using Cohen's kappa (κ) coefficient.

The findings were categorized into three groups as follows: mass enhancement; non-mass enhancement (NME); and associated findings. BI-RADS 4 was considered in the presence of each suspected feature and was

Table 1. Pulse sequence parameters for abbreviated and standard MRI protocols.

	Standard protocol					
					Abbreviated protocol	
Parameter	Ax 3D T1	Ax T2 FSE	Ax DWI	Cor 3D LAVA	Pre-contrast T1 LAVA	Post-contrast T1 LAVA
TR/TE (ms)	7/ 3	4746/102	3942/85	Min full	5/2	5/2
Flip angle	160	111	160	12	12	12
Slice thickness (mm)	2	5	5	3	2	2
FOV (mm)	380	360	320	300	340	340
Matrix size (mm)	384×384	320×256	96×192	288×192	384×320	384×320
Fat saturation	No	Yes	Yes	No	Yes	Yes

3D, three-dimensional; DWI, diffusion-weighted imaging; FOV, field of view; FSE, fast spin-echo; MRI, magnetic resonance imaging; TE, echo time; TR, repetition time.

upgraded to BI-RADS 5 in the presence of any of the associated findings.

Data collection

All the following data were recorded for all patients: (i) age: years; (ii) type of evaluation: screening or diagnostic (i.e. defining the extent of known cancer and evaluation of metacentric or multifocal or contralateral cancer, before and after neoadjuvant chemotherapy assessment, metastatic axillary lymphadenopathy of unknown primary in patients with negative ultrasonography and mammography, and recurrence of breast cancer); (iii) risk of breast cancer: average (<15%) or elevated risk (>15%) of lifetime risk; (iv) amount of fibroglandular tissue and background parenchymal enhancement; (v) suspected features: in mass findings these included speculated or irregular margin, heterogeneous, or rim enhancement, and in non-mass findings these included clumped, clustered ring, linear, or segmental enhancement pattern; (vi) associated findings: axillary lymphadenopathy and invasion to nipple, skin, pectoralis muscle, or chest wall; and (vii) interpretation time of MIP and abbreviated and standard protocol images.

Statistical analysis

Data are presented as mean ± standard deviation for continuous variables and number (percentage) for categorical variables. The standard MRI full protocol was considered as the gold standard diagnostic modality with respect to the presence or absence of BI-RADS 4 or 5. The results of the abbreviated MRI protocol and MIP were compared with the standard. Concordance was considered if two protocols showed the same BI-RADS. BI-RADS 4 or 5 were considered positive findings, and BI-RADS 1–3 categories were considered negative findings. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were calculated. The statistical analyses were performed using SPSS version 26 (IBM Corp., Armonk, NY, USA).

Table 2. Characteristics of study participants.

Descriptive results	Variable
No. of participants	408
Age (years)	43.56 ± 9.90
Risk factor	
High risk	195 (47.8)
Without risk factor	213 (52.2)
Type of exam	
Screening	249 (61)
Diagnostic	159 (39)
Fibro-glandular tissue	
F1	37 (9.1)
F2	116 (28.4)
F3	177 (43.4)
F4	78 (19.1)
Background parenchymal enhancement	
Minimal	184 (45.1)
Mild	169 (41.4)
Moderate	47 (11.5)
Marked	8 (2)
Standard protocol BI-RADS	
1	95 (23.3)
2	112 (27.5)
3	93 (22.8)
4	81 (19.9)
5	27 (6.6)

Values are given as n (%) or mean ± SD.

Results

The data of 408 women (mean age = 43.5 ± 9.9 years) were evaluated, of which 249 (61%) studies were done for screening and the rest for diagnostic purposes. Of all participants, 195 (47.8%) were classified in the high-risk category. BI-RADS 4–5 was detected in 108 (26.5%) participants. There was almost perfect agreement between the radiologists' report ($\kappa = 0.979$, 95% confidence interval [CI] = 0.965–0.993; $P < 0.001$). The characteristics of all participants are presented in Table 2. Total findings of three protocols (MIP, abbreviated, and standard full protocol) are presented in Table 3.

The mean total acquisition times for abbreviated and standard protocols were approximately 4 min and 30 min, respectively. Average interpretation times for MIP and abbreviated and standard MRI protocols were approximately 30 s, 2 min, and 15 min, respectively.

The abbreviated MRI showed 99% concordance with the standard protocol. The concordance with the standard

Table 3. Total findings of MIP, abbreviated and standard full protocols.

	Standard protocol	Abbreviated	MIP
Results			
Suspicious	301 (73.8)	299 (73.3)	301 (73.8)
Not suspicious	107 (26.2)	109 (26.7)	107 (26.2)
Associated findings			
None	367 (90)	367 (90)	379 (92.9)
Axillary LAP	34 (8.3)	34 (8.3)	25 (6.1)
Nipple retraction/	2 (0.5)	2 (0.5)	2 (0.5)
invasion	3 (0.7)	3 (0.7)	1 (0.2)
Skin thickening	2 (0.5)	2 (0.5)	1 (0.2)
Architectural distortion			
BI-RADs			
1+2	207 (50.7)	206 (50.5)	206 (50.5)
3	93 (22.8)	93 (22.8)	97 (23.8)
4	81 (19.9)	83 (20.3)	85 (20.8)
5	27 (6.6)	26 (6.4)	20 (4.9)

Data are presented as frequency (%).
LAP, lymphadenopathy; MIP, maximum intensity projection.

protocol was higher for the abbreviated protocol compared to MIP in screening (99.6% vs. 92.8%) as well as diagnostic settings (98.1% vs. 88.7%) (Table 4). There was no discordance between abbreviated and standard protocol in the evaluation of associated findings.

The diagnostic value of abbreviated MRI and MIP protocols compared to the standard full protocol is shown in Table 5, in view of the total, screening, and diagnostic setting. The abbreviated protocol in the screening protocol was exactly similar to the standard full protocol in detecting the suspicious mass and non-mass enhancement. Furthermore, in the diagnostic setting, all values were higher than 95%. In both screening and diagnostic settings, all values of the abbreviated MRI were higher than the MIP protocol.

Table 4. Concordance and discordance results of MIP, and abbreviated and standard full protocols.

	Concordance	Discordance
Total setting		
MIP vs. standard protocol	372 (91.2)	36 (8.8)
MIP vs. abbreviated	375 (91.9)	33 (8.1)
Abbreviated vs. standard protocol	404 (99)	4 (1)
Screening setting		
MIP vs. standard protocol	231 (92.8)	18 (7.2)
MIP vs. abbreviated	231 (92.8)	18 (7.2)
Abbreviated vs. standard protocol	248 (99.6)	1 (0.4)
Diagnostic setting		
MIP vs. standard protocol	141 (88.7)	18 (11.3)
MIP vs. abbreviated	144 (90.6)	15 (9.4)
Abbreviated vs. standard protocol	156 (98.1)	3 (1.9)

Values are given as n (%).
MIP, maximum intensity projection.

Discussion

Our findings point that an abbreviated MRI protocol is robust in screening and diagnostic settings to find suspicious findings of BI-RADS 4-5 categories with an acceptable accuracy of higher than 98%. The abbreviated breast MRI protocol with less acquisition time and cost can be considered to screen patients with an intermediate risk of breast cancer to detect occult cancer.

Efforts have been taken to introduce the optimal MRI protocol for breast cancer with minimum time and cost since the introduction of abbreviated MRI in 2014 (8). However, there is no common consensus regarding the selected sequences; and methods and diagnostic accuracies are widely different among studies (2). Kuhl et al. reported sensitivity, specificity, and NPV of 100%, 94%, and 100%, respectively, using unenhanced and first post-contrast T1W without fat saturation and first subtraction and MIP (8). We used T1 fat-saturated pre-contrast and first and second fat-saturated post-contrast series with their subtraction and MIP of two first post-contrast sequences in a heterogeneous group of patients (screening and diagnostic) and based on the BIRADS category. Our diagnostic accuracy, sensitivity, specificity, PPV, and NPV in the abbreviated protocol were 100%, 99.3%, 98.2%, 100%, and 99.5%, respectively, which was in line with Kuhl et al. and five other similar studies (7,8,14,15). However, protocols and populations in these studies were widely different.

Except for Kuhl et al., other studies included T2-weighted (T2W) images into their abbreviated protocol. Obtaining T2W images adds about 4–6 min to scanning time and about 2.5 min to interpretation time (7). However, Heacock et al. and Dialani et al. concluded that T2W images have no significant added value on accuracy (16–18). Given that we are looking for BI-RADS 4–5

Table 5. Diagnostic value of abbreviated MRI and MIP protocols compared to standard full protocol.

Test	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Total setting					
Abbreviated protocol					
Total (mass + NME)	100	99.3	98.2	100	99.5
Mass	98.3	100	100	99.7	99.8
NME	97.4	100	100	99.4	99.5
MIP	89.7	96.3	89.7	96.3	94.6
Screening setting					
Abbreviated protocol					
Mass	100	100	100	100	100
NME	100	100	100	100	100
MIP	83.8	97.6	86.1	97.2	95.6
Diagnostic setting					
Abbreviated protocol					
Mass	97.7	100	100	99.1	99.4
NME	100	98.2	95.9	100	98.7
MIP	92.9	93.3	91.5	94.3	93.1

MIP, maximum intensity projection; NME, non-mass enhancement; NPV, negative predictive value; PPV, positive predictive value.

lesions based on their abnormal enhancement, we excluded the T2 or T1 non-fat saturation series, which are mainly used to evaluate the morphology. Besides, T2W images could potentially reduce the B3 category (4,19). We also included second post-contrast images to our abbreviated protocol for detecting low-grade cancers. Kim et al. also showed that using only the first post-contrast images could miss 15% of cancers (20).

Most previous studies assessed the accuracy of abbreviated MRI in screening settings; two studies (13,21) used this technique for surveillance of treated cancer. These studies illustrated that accuracy and NPV of abbreviated MRI are high and more effectively depict morphological distortion from recurrence than mammography. We conducted our study in both screening and diagnostic settings. Our findings showed an overall concordance rate of 99% between abbreviated and standard protocols, with no significant difference between the screening (99.6%) and diagnostic populations (98.1%).

Taken together, we believe the findings of this study could provide physicians with a better insight towards breast cancer surveillance and diagnosis using abbreviated MRI protocol. We suppose that abbreviated protocol could supersede the conventional modalities as it possesses higher accuracy in cancer detection with the comparable time for scanning and interpretation. Performance of the abbreviated protocol in the evaluation of associated findings was in concordance with standard protocol in our study (7,12). The diagnostic performance of the abbreviated MRI protocol was promising; however, further investigations are required to confirm our findings.

The present study has some limitations. We assessed BI-RADS 4–5, but there was a considerable number of BI-RADS 3 (22.8%), which caused more recall rate and excessive cost. A decrease in BI-RADS 3 has been reported in two studies as 37% and 18%, respectively; it should be considered that both studies did not include T2 in their abbreviated protocol (18,19). Therefore, further evaluation is needed to determine the impact of BI-RADS 3 in screening and diagnostic performance of abbreviated protocol and choosing its sequences. Other new techniques such as ultrafast MRI are emerging too, which is based on early wash in the kinetic curve; however, this technique is not available in all units and needs special coil and sequences with high temporal resolution. Besides, it is not standardized yet, and missing slow-growing cancer could be its pitfall (12). Another potential limitation of abbreviated and standard MRI protocols for screening purposes is background parenchymal enhancement (BPE), which could cause problems in the timing of the scan for the MRI center and could affect interpretation; however, no study evaluated the effect of BPE on the diagnostic accuracy of abbreviated MRI. This study was conducted in a quaternary referral center for breast cancer with high-quality 3-T MRI and high agreement between two radiologists could be due to the high-quality equipment and expertise in image interpretation. More large-scale multicentric studies are needed in other clinical settings to confirm our results.

In conclusion, abbreviated MRI protocol for breast cancer showed promising results not only in screening breast cancer but also in diagnostic settings, including preoperative staging purposes. Taking into consideration an immense decrease in acquisition and interpretation time could make this protocol more feasible in larger populations.

Declaration of conflicting interests

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