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MR Imaging Features of Fibrocystic Change of the Breast

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Abstract

Purpose—Studies specifically reporting MR imaging of fibrocystic change (FCC) of the breast are very few and its MR imaging features are not clearly known. The purpose of this study was to analyze the MR imaging features of FCC of the breast.

Materials and Methods—Thirty one patients of pathologically proved FCC of the breast were retrospectively reviewed. The MRI study was performed using a 1.5 T MR scanner with standard bilateral breast coil. The imaging protocol consisted of pre-contrast T1W imaging and dynamic contrast-enhanced axial T1W imaging. The MRI features were interpreted based on the morphologic and enhancement kinetic descriptors defined on ACR BIRADS-MRI lexicon.

Results—FCC of the breast had a wide spectrum of morphologic and kinetic features on MRI. Two types of FCC were found, including a more diffuse type of non-mass lesion (12/31, 39%) showing benign enhancement kinetic pattern with medium wash-in in early phase (9/10, 90%) and a focal mass type lesion (11/31, 35%) with enhancement kinetic usually showing rapid up-slope mimicking a breast cancer (8/11, 73%).

Conclusion—MRI is able to elaborate the diverse imaging features of fibrocystic change of the breast. Our result showed that FCC presenting as focal mass type lesion were usually over-diagnosed as malignancy. Understanding MR imaging of FCC is important to determine which cohort of patients should be followed up alone or receive aggressive management.

Keywords

Fibrocystic change; Breast; MRI

INTRODUCTION

Fibrocystic change (FCC) is a common, non-cancerous condition that affects more than 50% of women [1]. The cause of FCC is related to the response of the breast tissue to monthly changes in levels of estrogen and progesterone. Women with FCC may experience an increase in size of the lumpy areas in the breast. Although FCC is not a well-established risk factor for developing breast cancer, it sometimes might simulate or make it more difficult to detect a breast cancer by physical examination. In this situation, further examination using imaging modalities such as sonography, mammography, and MR imaging will be needed. In most situations, FCC is a diffuse process. Occasionally, FCC might appear as a focal discrete lesion mimicking a tumor in clinical, radiographic, gross, and microscopic appearance. Although the imaging appearances of some of the histologic subtypes of FCC, such as sclerosing adenosis,

focal fibrosis, and apocrine metaplasia, have been previously described [2-4], MR imaging of FCC has been reported upon only once, and has not been reported specifically with regard to focal FCC [5].

Although mammography is the first line study tool, the dense breast tissue usually makes it less optimal. Using high resolution anatomic MRI and dynamic contrast enhanced MRI, tumors can be characterized based on their morphology and enhancement kinetics for diagnosis. In all studies it has been consistently demonstrated that MRI detects malignant cancers, which are occult on mammogram and ultrasound. However, despite its high sensitivity, MRI also detects many benign lesions. The low specificity may lead to great anxiety to patients, and many unnecessary biopsy or over-treatment. The purpose of this study is to analyze the MR imaging features of FCC of the breast based on ACR BI-RADS MRI lexicon. In selected patients, who received breast MRI prior to biopsy and with suspicion of malignancy after the imaging study, MR spectroscopy for choline detection was further performed. Studies conducted at 1.5T have shown that in vivo MRS can be used to distinguish between malignant and benign tissues based on the premise that total choline-containing compounds (Cho) are only detectable in malignancies [6]. Familiarity of and understanding the MRI characteristics of FCC is important, when evaluating patients with suspicious breast lesions on MRI, to decrease the rate of false-positive findings and to diminish unnecessary biopsies or aggressive management. This study was performed to evaluate if FCC of the breast shows characteristic MR imaging features and can be diagnosed correctly.

MATERIALS AND METHODS

Patients

From 450 patients who had breast MRI in the past five years (Jan. 2002 to Dec. 2006), 31 patients with pathologically proved FCC of the breast were retrospectively reviewed. The study was approved by the Institutional Review Board and was HIPAA compliant. All participants gave written informed consent. Patients' age was from 30 to 74 years old (mean age, 52 y/o). Information of mammography (N=25) or sonographic examination (N=19) results were available in 26 patients. In 5 patients, information of mammography and sonography were not available in their chart. All these 31 patients received breast MRI examination because of either having suspicious lesions found using mammography or sonography, or being suspected to have breast lesions after palpation by clinicians. Eleven patients who showed suspicious malignant lesions on routine MRI also had choline estimation on the suspicious tumor region. Of them, 7 received single-voxel MR spectroscopy of choline quantification and 4 patients had multi-voxel MR spectroscopy of choline signal-to-noise measurement.

The pathological reports were obtained by excision biopsy in 8 lesions and core biopsy in 23 lesions. Sixteen patients eventually received surgical operation of the suspected breast lesion, including 12 lumpectomies and 4 mastectomies. Four mastectomies performed included 2 patients with concomitant contralateral invasive cancer, 1 patient of BRCA1 carrier with prophylactic mastectomy, and 1 patient showing malignant feature of the FCC lesion.

When reviewing a surgical specimen, the pathologist was aware of the location of the suspected lesion detected by MRI. Special attention was paid to the suspicious areas, if any, in the 4 mastectomy specimens. Twelve patients received lumpectomy of the FCC after wire localization of the lesion using sonography. Before the sonography-guided wire localization procedure, the breast radiologist had reviewed the MRI report, checked the location of the enhanced lesion, and correlated it with the sonographic finding. Fifteen patients did not undergo operation after biopsy and were followed up by the outpatient department. Two of these 15 patients had follow-up breast MRI studies and showed complete disappearance of the enhanced lesion noted in the previous MRI, hence proving the correct localization and biopsy of the

suspicious lesions. The remaining 13 patients had follow-up mammography which showed no definite abnormality.

MR Imaging Protocol

The MRI study was performed using a 1.5 T Phillips Eclipse MR scanner with a standard bilateral breast coil (Philips Medical Systems, Cleveland, Ohio). The imaging protocol consisted of high-resolution pre-contrast imaging and dynamic contrast-enhanced axial imaging. Sagittal view unilateral T1-weighted pre-contrast images were acquired from the breast of concern, using a spin echo pulse sequence with TR = 1000 ms, TE = 12 ms, thickness 3.5mm. Following this, a 3D SPGR (RF-FAST, TR = 8.1 ms, TE = 4.0 ms, flip angle = 20°) pulse sequence with 16 frames (repetitions) was prescribed for bilateral dynamic imaging. The scan time was 42 sec per acquisition. The sequence was repeated 16 times for dynamic acquisitions, four pre-contrast, and 12 post-contrast sets.

After the dynamic scan was completed, subtraction images were generated on the scanner console, by subtracting the pre-contrast images acquired in Frame #3 from the 1-min post contrast enhanced images acquired in Frame #6. The enhancement of the breast tissue and breast lesion in the subtracted images was presented as either gray scale images or color-coded images. In color-coded images, the enhancement magnitude was presented according to the color range of 250 arbitrary units. The maximum intensity projections (MIPs) were also generated from the set of subtraction images.

The enhancement kinetics were analyzed from manually-drawn tumor ROI (region of interest) on each imaging slice containing the lesion, encompassing enhanced tissues on subtraction images taken at 1-min post injection. The MIP was used as the reference for ROI drawing. This approach minimized subjective arbitrary ROI selection by the operator, also since it was based on early enhancements at 1-min after injection, only well perfused tissues were included. The enhancement time course was calculated by subtracting the mean pre-contrast signal intensity (mean of first 4 frames) from each of the subsequent 12 post-contrast signal intensities. The fitting process was carried out with software developed in-house using Matlab (version 6.0.0.88, The MathWorks, Inc.). The measured enhancement kinetics was analyzed using a 2-compartmental pharmacokinetic model to obtain respective vascular and extravascular contributions [7]. The summation of these two components was regarded as overall (or total) tumor enhancement.

For single-voxel acquisition MR spectroscopy, point-resolved spectroscopic (PRESS) sequence [8] was used for a correct localization of the volume on the centered lesion of interest. The spectroscopic voxel was placed on subtraction image acquired at 1-min post injection. The voxel size was $1.8 \times 1.8 \times 1.8$ (or, $2.0 \times 2.0 \times 2.0$) cm³. A fully relaxed, unsuppressed spectrum was also acquired to measure the water and lipid peaks. Raw data acquired was then transferred to a PC and processed by advanced signal processing software. The choline-containing compounds concentration was calculated using water as an internal reference [9,10].

For multiple-voxel chemical shift imaging, the CSI grid was carefully positioned to maximize coverage of the hypointense lesion. The voxel size was $1.0 \times 1.0 \times 1.2$ cm³. The signal-to-noise ratio (SNR) of the Cho peak was calculated as the ratio of Cho peak height to background noise level. If there was any single voxel with Cho SNR > 2, the lesion was categorized as with positive Cho [11].

Interpretation of MR Imaging

Mammography and sonography was interpreted by a senior radiologist with abundant experience in breast imaging. MR imaging was interpreted by a board certified senior

radiologist with 18 years experience in interpreting body imaging and two and half years in interpreting breast MRI. For all different imaging studies, ACR BIRADS assessment categories (0-5) were applied for each patient. The diagnosis of MRI was based on the morphologic and enhancement kinetic features of ACR BIRAD-MRI lexicon. The morphologic criteria included mass type lesion, including focus/foci (smaller than 5mm) and mass (equal to or greater than 5 mm), and non-mass enhancement lesions (patchy, linear, ductal, segmental, regional, multiple regions, and diffuse enhancement). When a breast had more than one lesion and those lesions were not connected, it was defined as multiple lesions. The evaluation of enhancement kinetic curve was based on initial phase (within the first 2 minutes or when the curve starts to change), and late phase (after 2 minutes or after the change). The initial enhancement phase is further categorized into fast, medium, and slow. The late enhancement phase is described as persistent, plateau, and washout [12-16].

Statistics

Fisher's exact test was used to compare the diagnostic performance of mammography, sonography, and MRI for fibrocystic change of the breast.

RESULTS

Clinical Information

Of the 31 patients, 11 had contra-lateral malignant lesions, including 9 invasive ductal carcinomas, 1 infiltrating lobular cancer and 1 tubular cancer. Of the 19 patients with sonography examination, 11 patients showed hypoechoic lesions suspicious of breast tumors. The other 8 patients did not demonstrate any abnormalities. Of the 25 patients with mammography examination, 10 showed increased opacity of speculated or irregular margin suspicious of tumor and 12 showed branching, pleomorphic or micro-calcification. Another 3 patients did not show any demonstrable lesions.

MR Imaging Findings

On MRI, two types of lesions were found including more diffuse type and focal type. For 12 lesions (12/31, 39%) presenting with more diffuse type of FCC, non-mass type of enhancement lesions were found, including 9 regional enhancement, 2 linear enhancement and 1 diffuse heterogeneous enhancement. All of the 9 patients with regional enhancement showed homogeneous low enhancement magnitude by subjective evaluation on the color coded image, which showed yellow or green enhancement scale in the color bar (please refer to Figure 1B). Eleven patients with FCC (11/31, 35%) showed focal type lesion and MRI demonstrated mass type of enhancement lesion with size smaller than 2cm in 6 patients and focus lesion (equal or smaller than 4mm) in 5 patients. Overall, the size of the mass type lesion was from 4mm to 20mm (mean 8mm). In 8 patients, breast MRI did not show definite evidence of abnormal enhancement in the affected breast.

Morphologically, 3 lesions of focal FCC were diagnosed as malignant because 2 lesions showed irregular margins in the subtracted post-enhanced image and 1 lesion showed spiculated margin in the pre-enhanced image. The other 8 lesions of focal FCC with smooth lesion margins and all 12 lesions of diffuse type FCC were diagnosed as benign.

Kinetic curves were created in 21 patients, including 10 non-mass lesions and 11 mass type lesions. Two patients with non-mass type of linear enhancement and regional enhancement were not measured for kinetic enhancement curve because of difficulty in placing the region of interest (ROI) on the linear enhanced area and too faint enhancement respectively. Nine non-mass type lesions (9/10, 90%) showed benign enhancement kinetics of medium or slow up-slope followed by persistent enhancement. One non-mass lesion and 8 mass type lesions

(8/11, 73%) showed rapid up-slope followed by wash-out (n=6) or reaching plateau (n=3) mimicking a malignancy. Three mass type lesions showed medium up-slope with persistent enhancement which was suggestive of a benign lesion (Table 1). Using either morphological or kinetic criterion, 11 patients were suspected as malignant lesions. Fig. 1-4 showed different MR imaging features of FCC of the breast. Fig.5 showed a case of focal FCC and its follow-up MRI post biopsy.

Regarding choline quantification, two of the eleven patients showed positive choline levels, one measured by single-voxel (1.16mmol/kg) and the other by multi-voxel chemical shift imaging (SNR =3) MR spectroscopy. These two patients showed diffuse and patch enhancement after contrast agent injection.

MR Imaging Correlated with Mammography and Sonography

Table 2 summarized the mammography, sonography, MR imaging findings, MR spectroscopic findings, and the ACR BIRADS lesion categories of these 31 patients when available. Table 3 compared the diagnostic rate of lesion classification as either benign (categories 1-3) or malignant (categories 4-5) on mammography, sonography, and MRI. Overall, mammography diagnosed ACR BIRADS categories 1-3 lesions in 12 patients and categories 4-5 lesions in 10 patients, and sonography diagnosed 10 categories 1-3 lesions and 9 categories 4-5 lesions. MRI diagnosed 20 categories 1-3 lesions and 11 categories 4-5 lesions. No significant difference in the correct diagnosis of FCC was found between mammography and MRI ($P=0.79$), and between sonography and MRI ($P=0.55$).

Table 4 demonstrated the corresponding mammography and sonography findings to different MRI morphology. Three groups of patients with different MRI features (12 non-mass enhancement, 11 mass type, and 8 without abnormality) were correlated with their mammography and sonography findings. Of the 10 patients showing increased opacity of speculated or irregular margin suspicious of tumor in mammography, 7 patients (70%) presented as a mass type lesion in MRI. Of the 11 patients showing hypoechoic lesions suspicious of breast tumors in sonography, 7 patients (64%) presented as mass type lesions in MRI. In eight patients who did not show enhancement in MRI, mammography demonstrated microcalcification in 6 patients (75%) and no definite finding in one patient. Two of these eight patients also showed no significant finding in sonography.

DISCUSSION

Typical clinical symptoms of the patient and physical examination of the physician can exclude most cases of FCC. In some patients, however, further imaging studies are necessary when suspicion arises in the nature of the palpated lump.

Mammography cannot reliably diagnose FCC due to wide variation of imaging findings. It usually presents as a diffuse nodular mass on mammogram. When discrete mass or density is found, it mimics breast cancer. The spectrum of sonographic appearances in histologically proven focal FCC of the breast was studied by Shetty MK et.al [17]. They studied 60 focal FCC and found that the sonographic features of FCC are, not specific enough to differentiate them from other breast lesion types. Similarly, in our study, 9 of 11 hypoechoic lesions were diagnosed as ACR BIRADS categories 4-5.

When correlative study was performed, it was found that the non-mass type of FCC on MRI cannot be correctly diagnosed by mammography or sonography. In mammography, they appear either as mass opacities of discrepant size or non-specific micro-calcifications. In sonography, they either appear as hypoechoic mass lesions, which were discrepant in size with the MRI, or no significant findings. Better correlation was, however, found for mass type lesions. For 11

mass type lesions shown on MRI, 7 patients also presented with a hypoechoic mass lesion on sonography and a mass opacity on mammography.

In our study, it was found that, when comparing the diagnostic performance of MRI with mammography and sonography for FCC, no significant difference existed between these imaging modalities. All three imaging modalities had high over-diagnostic rate. Since there is a trend to use MRI for screening high-risk young women, diagnostic ambiguity will happen due to the very common condition of FCC identified in the same age cohort. MRI for detection of breast cancer should be performed in the second and third week of the menstrual cycles when FCC shows the weakest enhancement [18]. This will reduce the interference of unusual strong glandular enhancement coming from the FCC tissue and therefore decrease false-positive diagnostic rate for breast cancer.

Studies specifically on MR imaging of FCC are very few and the case number is limited. Maurice et al. [5] reported that FCC most often presents as a mass or as a non-mass like regional enhancing lesion with benign enhancement kinetics. Morphologically, two patients were suspected to have malignancies due to irregular tumor margins. According to the enhancement kinetics, 3 patients were suspected to have a malignancy due to their initial rapid-upslope and late-phase plateau. With either criterion, 5 patients in total were suspected for malignancy. Arriving at the correct diagnosis of FCC to reduce false-positive findings remains problematic.

Using either morphological or kinetic criterion, 11 patients were suspected as malignant lesions in our study. Of them, 9 were suggested by kinetic features and 3 by morphological features. From Maurice et al and our study, morphological criteria have fewer false positive diagnoses of malignant lesions than that of kinetic criteria. This finding was comparable to that of Goto et al. who analyzed 144 malignant and 60 benign breast lesions and showed that the sensitivity and specificity of the morphologic criteria were significantly higher than those of the enhancement patterns [19].

Eleven FCC in our study presented with focal type lesions smaller than 2cm. A recent article analyzed the impact of lesion size on the positive predictive value (PPV) of biopsy in MRI-detected breast lesions, and found that the frequency of malignancy increased significantly with lesion size. Lesions less than 5 mm in size had a 3% chance of being malignant (1 out of 37 lesions). Lesions 5-9 mm and 10-14 mm in size had respective malignancy rates of 17% (44 of 254 lesions) and 25% (37 out of 151 lesions) [20]. They concluded that biopsy is rarely necessary for lesions smaller than 5 mm.

Two of our patients with concomitant contra-lateral malignancy led to mastectomies of the focal FCC in the affected breast. In a study of 48 incidentally detected breast lesions in 299 patients prepared for breast-conserving therapy, 25 lesions were proved to be benign and 23 proved to be malignant. Lesions of over 10 mm tended to be malignant and lesions equal or less than 5 mm tended to be benign [21]. A large-scale study in evaluation of 969 breast cancer patients showed that MRI detected 3.1% (30/969) of clinically and mammographically occult breast cancer in the contralateral breast. Although the negative predictive value of MRI was 99%, the estimated positive predictive value of a positive MRI examination was only 21% [22]. Proton MR spectroscopy provides a noninvasive, biochemical measure of tumor metabolism. Some benign cases such as FCC, as shown in 2 patients in our study, however, also show positive choline level. Kim JK et al [23] showed that Cho was not only detected in a number of benign diseases including tubular adenomas and FCC but also in normal feeding breast tissue. Our limited data showed, although choline might be detected in benign disease, the choline level is lower than that of the malignant breast cancer (our unpublished data).

Several limitations existed in our study. The spatial resolution of MRI protocol used in this study was suboptimal; which needs to be improved to enhance diagnostic accuracy of small

tumor foci. This imaging protocol was set in year 2002 under an NIH funding support. The relatively low spatial resolution was selected to cover the whole breast, also to reach a temporal resolution of 42 sec, which was critical in analysis of enhancement kinetics. In this study, subtraction was used to obtain enhancement maps, which was susceptible to patient motion. We have moved the study to a 3.0T scanner, and our current protocol has improved spatial resolution, as well as fat-suppression. Post-contrast enhanced images can be directly evaluated without subtraction; thus less prone to the motion problem. One major difficulty of breast MRI is to spatially correlate MRI findings with pathological findings. Although MRI-guided biopsy has become available, it is much more complicated compared to mammogram or ultrasound guided biopsy; thus was not used in this study.

CONCLUSION

Two types of fibrocystic change of the breast were found including more diffuse type and focal type. Each type had different morphological features, i.e. more diffuse type showed non-mass type of enhancement and focal type showed mass type of enhancement. When FCC presented with non-mass type lesion, especially regional enhancement, it usually showed benign enhancement kinetics with low enhancement magnitude on MRI. While, most of the focal type FCC lesion showed malignant kinetic mimicking a breast cancer. Understanding the spectrum of MR imaging of FCC is important for clinicians to determine which cohort of patients should be followed up alone or receive more aggressive management.

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Figure 1. 31-year-old woman with fibrocystic change of the breast. Figure 1A: pre-contrast T1 weighted imaging, Figure 1B: color map image with color bar of 250 arbitrary units for reference, Figure 1C: kinetic enhancement curve. Note the lesion with light regional enhancement in Figure 1B (arrow) and persistent enhancement kinetics in Figure 1C, suggesting a benign breast lesion. In Figure 1B, using a 2-compartmental pharmacokinetic model for measuring enhancement kinetics, the summation of the vascular and extravascular components was regarded as overall (or total) tumor enhancement. Retrospective review of the mammography showed benign calcification in both breasts and sonography did not find any significant lesions.

Figure 2.

45-year-old woman with fibrocystic change of the breast. Figure 2A: pre-contrast T1 weighted imaging, Figure 2B: color map image, Figure 2C: kinetic enhancement curve. No definite abnormality can be identified in the Figure 2A. Note the diffuse heterogeneous enhancement in both breasts with medium up-slope and reaching the plateau, a feature identified in the both breasts. Sonography showed a 10x8mm hypoechoic lesion in the left breast, which did not match the MR imaging findings (not shown here). Mammography did not demonstrate any abnormal lesions.

Figure 3. 49-year-old woman with focal fibrocystic change of the right breast. Figure 3A: pre-enhanced T1 weighted imaging, Figure 3B: color map image, Figure 3C: kinetic enhancement curve. Note the speculated appearance of the lesion in Figure 3A (black arrow), which raises the suspicion of malignancy. Figure 3B shows the well-defined strongly enhanced small lesion well (white arrow). Kinetic curve shows rapid up-slope with mild washout, also suspicious for malignancy.

Figure 4.

64-year-old woman with invasive ductal carcinoma in the left breast and focal fibrocystic change in the right breast. Figure 4A shows the small enhanced breast cancer in the left breast (white arrow). Figure 4B shows the focal fibrocystic change in the right breast (white arrow). Note the central filling defect of the lesion due to previous needle biopsy. Kinetic curve for the right breast lesion in Figure 4C shows continuous enhancement, indicating benign process or in-situ tumor.

Figure 5.

49 year-old woman with focal fibrocystic change of the right breast. Sonography of the right breast showed an 8mm hypoechoic lesion in the right breast. A pre-enhanced T1 weighted axial image (Figure 2A) shows a small hypointense lesion in the right breast (black arrow). The post-enhanced subtracted color coded image (Figure 5B) demonstrates an enhanced lesion in the same location (white arrow). Core biopsy of the lesion under sonography guidance showed fibrocystic change with focal sclerosing adenosis. Follow-up MRI study a half-year later (Figure 5C) reveals that the previous enhanced lesion is removed. Only faint enhancement in the same location is noted (white arrow).

Table 1
MR Morphology Related to Kinetics Features in 21 Patients

Morphology\ Kinetic (N= 21)	Fast-washout	Fast-plateau	Medium/Slow-persistent
Mass type lesion (N=11)	6 (55%)	2 (18%)	3 (27%)
Non-mass lesion (N=10)	0 (0%)	1 (10%)	9 (90%)

Table 2

Summary of Imaging Findings in Thirty One Patients

Case BIRADS	Mammography BIRADS	Mammo BIRADS	Sonography	Sono	MRI-Morphology	MR-Kinetics	MRI	MRS
1	linear calcification	4	N/A	N/A	no enhancement	N/A	1	N/A
2	N/A	N/A	N/A	N/A	regional enhancement	B	3	N/
3	N/A	N/A	N/A	N/A	linear enhancement	N/A	3	N/A
4	mass opacity	4	N/A	N/A	regional enhancement	B	3	N/A
5	mass opacity	4	hypochoic lesion	4	focus	M	4	N/A
6	calcification	2	N/A	N/A	no enhancement	N/A	1	N/A
7	irregular mass	3	NSF	3	regional enhancement	B	2	N/A
8	spiculated mass	4	hypochoic mass	4	spiculated mass	M	5	N/A
9	N/A	N/A	N/A	N/A	regional enhancement	B	2	N/A
10	microcalcification	2	hypochoic mass	4	regional enhancement	N/A	2	N/A
11	abnormal density	3	NSF	1	focus	M	4	N/A
12	mass opacity	4	hypochoic lesion	3	focus	M	4	N
13	microcalcification	3	N/A	N/A	regional enhancement	B	2	N
14	calcification	4	hypochoic lesion	4	no enhancement	N/A	1	N/A
15	N/A	N/A	N/A	N/A	linear enhancement	M	4	N
16	N/A	N/A	N/A	N/A	regional enhancement	B	2	N
17	benign calcification	2	NSF	2	regional enhancement	B	2	N
18	microcalcification	4	hypochoic lesion	3	no enhancement	N/A	1	N/A
19	NSF	0	N/A	N/A	no enhancement	N/A	1	N/A
20	mass opacity	4	hypochoic lesion	4	diffuse enhancement	B	2	(+) -CSI
21	N/A	N/A	NSF	1	no enhancement	N/A	1	N/A
22	benign calcification	2	NSF	2	regional enhancement	B	2	(+) -SV
23	microcalcification	0	NSF	1	no enhancement	N/A	1	N/A
24	benign calcification	2	N/A	N/A	no enhancement	N/A	1	N/A
25	mass opacity	4	hypochoic mass	4	mass type lesion	M	5	N
26	branching calcification	0	hypochoic mass	5	mass type lesion	M	5	N
27	mass opacity	4	hypochoic lesion	4	multiple foci	B	4	N/A
28	NSF	2	hypochoic lesion	4	mass	B	4	N
29	NSF	2	NSF	2	mass	M	5	N
30	calcification	3	NSF	2	mass	B	3	N/A

Case	BIRADS	Mammography	BIRADS	Mammo	BIRADS	Sonography	Sono	MRI-Morphology	MR-Kinetics	MRI	MRS
31		ill-defined opacity	3		N/A		N/A	focus	M	5	N/A

N/A: not available; NSF: no significant findings B: benign enhancement kinetics; M: malignant enhancement kinetics; N: negative choline detection; CSI: chemical shift imaging; SV: single voxel
Note: MRI diagnosis was based on the combination of both morphological and kinetic features

Table 3

Rate of lesion classification as benign or malignant on mammography, sonography and MRI

	ACR BI-RADS 1–3 (correct diagnosis)	ACR BI-RADS 4–5 (overdiagnosis)
Mammography (<i>n</i> =25)	12 (48%)	10 (40%)
Sonography (<i>n</i> =19)	10 (53%)	9 (47%)
MRI (<i>n</i> =31)	20 (65%)	11 (35%)

No significant difference in the correct diagnosis of FCC between mammography and MRI ($P=.79$), and between sonography and MRI ($P=.55$).

MRI diagnosis was based on the combination of both morphological and kinetic features.

Table 4

Corresponding mammography and sonography to different MRI morphology

		Mass or density	Micro-calcifications	No significant finding
Nonmass, regional enhancements (<i>n</i> =12)	Mammography (<i>n</i> =7)	3	4	0
	US (<i>n</i> =5)	2	–	3
Mass-type enhancements(<i>n</i> =11)	Mammography (<i>n</i> =11)	7	2	2
	US (<i>n</i> =10)	7	–	3
No significant enhancements (<i>n</i> =8)	Mammography (<i>n</i> =7)	0	6	1
	US (<i>n</i> =4)	2	–	2