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Original Article *Özgün Araştırma*

THE IMPACT OF MAGNETIC RESONANCE IMAGING ON BI-RADS CLASSIFICATION AND MALIGNANCY PREDICTION IN ULTRASOUND-DETECTED NON-MASS BREAST LESION

Ultrasonografide Saptanan Kitlesel Olmayan Meme Lezyonlarında Manyetik Rezonans Görüntülemenin BI-RADS Sınıflandırmasına Etkisi ve Malignite Öngörüsüne Katkısı

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ABSTRACT

Objective: To assess the contribution of magnetic resonance imaging to Breast Imaging Reporting and Data System (BI-RADS) reclassification and biopsy decision making in patients with non-mass breast lesions identified on ultrasound.

Material and Methods: This retrospective study included 392 patients who underwent breast magnetic resonance imaging following the identification of non-mass breast lesions on ultrasound; 135 had histopathologic verification and were analyzed. BI-RADS categories on ultrasound and magnetic resonance imaging were compared, and reclassification patterns were defined as upgrade (ultrasound <4 to magnetic resonance imaging ≥4), downgrade (ultrasound ≥4 to magnetic resonance imaging <4), or stable. Diagnostic accuracy metrics were calculated using BI-RADS ≥4 as the threshold for clinically significant disease.

Results: Among 135 patients with pathology, of the lesions 64.4% were benign, 5.9% were high-risk, and 29.6% were malignant. Using BI-RADS ≥4, magnetic resonance imaging demonstrated higher sensitivity and negative predictive value (95.5% and 90.0%) than ultrasound (61.4% and 77.9%) but substantially reduced specificity (21.2% vs. 70.6%). Magnetic resonance imaging upgraded 48.8% of lesions and downgraded 4.7%. High-risk/malignant disease was detected in 23.8% of upgraded lesions, while all downgraded lesions were benign.

Conclusion: Magnetic resonance imaging meaningfully influences BI-RADS reclassification in non-mass breast lesions by improving lesion exclusion confidence but at the cost of lower specificity and reduced biopsy yield. Magnetic resonance imaging -driven downgrade appears safe and may help avoid unnecessary biopsies in selected cases.

Keywords: *Non-mass breast lesion, BI-RADS, magnetic resonance imaging, ultrasound, reclassification*

ÖZ

Amaç: Ultrasonografide kitlesel olmayan meme lezyonu saptanan hastalarda manyetik rezonans görüntülemenin Breast Imaging Reporting and Data System (BI-RADS) yeniden sınıflandırma sürecine ve biyopsi gerekliliğine etkisini değerlendirmek.

Gereç ve Yöntemler: Ultrasonografide kitlesel olmayan lezyon saptanan ve ardından manyetik rezonans görüntüleme yapılan toplam 392 hasta incelendi; histopatolojik doğrulaması bulunan 135 hasta analize dahil edildi. Ultrason ve manyetik rezonans görüntüleme (BI-RADS) kategorileri karşılaştırıldı ve yeniden sınıflandırma (kategori yükselmesi, kategori düşmesi veya stabil olarak) yapıldı. BI-RADS ≥4 klinik anlamlı hastalık eşiği olarak kabul edilerek tanısal doğruluk ölçütleri hesaplandı.

Bulgular: Patoloji doğrulaması olan hastalarda lezyonların %64,4'ü benign, %5,9'u yüksek riskli ve %29,6'sı malign bulundu. BI-RADS ≥4 eşik değeri kullanıldığında manyetik rezonans görüntüleme duyarlılık ve negatif prediktif değer açısından ultrasondan daha yüksek performans gösterdi (%95,5 ve %90,0), ancak özgüllük belirgin şekilde düşüktü (%21,2). Manyetik rezonans görüntüleme, olguların %48,8'inin kategorisini yükseltirken, %4,7'sini düşürdü. Kategorisi yükselen olguların %23,8'i yüksek riskli/malign iken, kategorisi düşürülen tüm olgular benign idi.

Sonuç: Manyetik rezonans görüntüleme, kitlesel olmayan lezyonlarda BI-RADS yeniden sınıflandırmayı anlamlı ölçüde etkilemekte ve maligniteyi dışlamada yüksek tanısal güven sağlamaktadır. Bununla birlikte, spesifitedeki düşüş nedeniyle biyopsi veriminde belirgin iyileşme sağlamamakta; kategorisi düşen olgularda gereksiz biyopsileri güvenle azaltma potansiyeli sunmaktadır.

Anahtar Kelimeler: *Kitlesel olmayan lezyon, BI-RADS, manyetik rezonans görüntüleme, ultrasonografi, yeniden sınıflandırma*

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INTRODUCTION

The evaluation of non-mass breast lesions (NMLs) remains a diagnostic challenge. Non-mass breast lesions on ultrasound (US) are typically described as areas of altered echotexture without a discrete space-occupying mass, architectural distortion, or focal shadowing, and their imaging terminology remains less standardized than that of mass lesions. In such diagnostically challenging cases, breast magnetic resonance imaging (MRI) may serve as a problem-solving tool, particularly when US findings are inconclusive or when lesion characterization may influence biopsy decisions.

Their ambiguous morphology and fluctuating clinical behavior complicate the diagnostic process.. Ultrasound is typically the first-line modality for breast symptom assessment and for supplemental screening in women with dense breast tissue. Characterization of NMLs in the US is often inconclusive. This uncertainty leaves many patients in a diagnostic gray area and can lead to unnecessary biopsies, delayed diagnosis, or overly frequent follow-ups.[1,2]

Magnetic resonance imaging offers additional value in assessing NMLs by revealing subtle enhancement patterns and parenchymal alterations with high sensitivity. The diagnostic contribution of MRI is particularly emphasized for BI-RADS 4 lesions, for which MRI has demonstrated a strong correlation with histopathological outcomes in multiple studies.[3,4] Moreover, several publications suggest that MRI may not only enhance malignancy prediction but also reduce unnecessary invasive procedures by increasing confidence in imaging-based decision-making.[5,6]

Recent research highlights that MRI reassessment of BI-RADS 3 lesions is clinically relevant, as this approach may reduce avoidable biopsies and guide safer surveillance strategies.[7,8] When paired with evolving management algorithms, integrating MRI data into BI-RADS categorization can improve both radiologic decisions and patient outcomes.

Collectively, the emerging literature suggests that the impact of MRI on BI-RADS reclassification and biopsy yield in NMLs represents an increasingly important area of investigation.[9] This line of research plays a significant role in enhancing early breast cancer detection while also contributing to the cost-effectiveness of healthcare systems.[6]

In this study, we aimed to assess the contribution of magnetic resonance imaging to Breast Imaging Reporting and Data System (BI-RADS) reclassification and biopsy decision-making in patients with non-mass breast lesions identified on ultrasound.

MATERIALS AND METHODS

Patient selection

This retrospective, single-center study was conducted with the approval of the Ethics Committee of Ankara Bilkent City Hospital (decision number: TABED 2/1683/2025; date: 10.12.2025) and included consecutive female patients who underwent breast US and breast MRI between January 2020 and July 2021 for the evaluation of NMLs. Patients were identified through the institutional radiology information system. A NML was defined as an area of altered tissue echotexture without a space-occupying mass on US.[10]

The age range of the patients included in the study was 29-77 years, with a median age of 44 years.

The initial study population consisted of 392 patients with NMLs detected on US. The following exclusion criteria were applied:

1. Missing breast MRI examination
2. History of breast surgery or breast cancer
3. Neoadjuvant chemotherapy before imaging
4. Lack of follow-up or incomplete imaging records

After exclusions, 392 patients who met the inclusion criteria and had MRI examinations available were included in the final imaging cohort. Among them, 135 patients had histopathologic verification after biopsy and were considered as pathology-confirmed subgroup. The remaining 257 patients did not undergo tissue sampling and constituted the non-verified subgroup, representing the real-world diagnostic population.

Ultrasound protocol

All US examinations were performed using a high-resolution US system (LOGIQ S8, GE HealthCare, Chicago, IL, USA) equipped with a linear-array transducer. The transducer operated in the 6–15 MHz frequency range. B-mode images were acquired following standardized scanning protocols. Patients were positioned in the supine oblique position.

Each lesion was categorized according to the American College of Radiology (ACR) BI-RADS Atlas, 5th edition.[11] For each lesion, the following data were recorded:

- BI-RADS category (category 1, negative; category 2, benign; category 3, probably benign (<2% likelihood of malignancy); category 4, suspicious (3%–94% likelihood of malignancy; subdivided into 4A, 4B, and 4C based on increasing suspicion); category 5, highly suggestive of malignancy (>95% likelihood of malignancy); and category 6, biopsy-proven malignancy.).
- Lesion laterality and location
- Presence or absence of family history of breast cancer

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- Whether second-look US was performed after MRI

BI-RADS 0 lesions were included in the analysis because they represented cases with incomplete ultrasound evaluation that subsequently underwent MRI for further characterization.

Magnetic Resonance Imaging protocol

All MRI examinations were performed using a 3-T MRI (Signa Pioneer, General Electric Medical Systems, Milwaukee, WI, USA) in the prone position using a 16-channel phased-array bilateral breast coil (Neo Coil 3.0 T 16-channel breast coil, General Electric Medical Systems, Milwaukee, WI, USA).

Breast MRI examinations were performed using a 3.0-T scanner with a dedicated bilateral breast coil. The imaging protocol included axial T1-weighted fast spin-echo (repetition time [TR]/echo time [TE], 484/8.5ms; slice thickness=5mm), axial and sagittal T2-weighted fat-suppressed fast spin-echo (TR/TE, 4786/82.5ms and 5116/83.5ms, respectively; slice thickness=5mm), and dynamic contrast-enhanced axial T1-weighted fat-suppressed sequence (TR/TE, 6.1/1.7ms; slice thickness=2.2mm) acquired before and after intravenous administration of gadolinium-based contrast agent (0.1mmol/kg) followed by a 20mL saline flush. Diffusion-weighted imaging was performed using single-shot echo-planar imaging with b-values of 50 and 800s/mm². Apparent diffusion coefficient (ADC) maps were automatically generated on the workstation.

All measurements were performed simultaneously by two radiologists with over ten years of experience in breast radiology.

Reference standard and subgroups

Histopathology served as the reference standard in patients who underwent biopsy. Pathology results were categorized as benign, high-risk (e.g., atypical ductal hyperplasia, atypical lobular hyperplasia, lobular carcinoma in situ, flat epithelial atypia, radial scar), or malignant, consistent with previously published pathology classifications.[12] Patients without pathology were analyzed separately to evaluate MRI-driven decision making in a real clinical context.

Statistical analysis

All statistical analyses were performed using SPSS software (version 31.0; IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean±standard deviation, and categorical variables as frequencies and percentages. Normality of distribution was assessed using the Kolmogorov–Smirnov test.

Diagnostic performance analyses were conducted for US and MRI using BI-RADS category 4 or higher (BI-RADS ≥4) as the biopsy threshold. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and the area under the Receiver Operating Characteristic (ROC) curve, expressed as the area under the curve (AUC), were calculated based on final histopathology, in which premalignant and malignant lesions were grouped together as positive outcomes.

Magnetic resonance imaging-driven BI-RADS changes were categorized as upgrade (US <4 to MRI ≥4), downgrade (US ≥4 to MRI <4), or stable classification. The association between MRI–US lesion correlation and the use of second-look US was assessed using the chi-square test. ROC analysis was performed to evaluate the ability of second-look US to predict BI-RADS upgrade. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 392 patients with NMLs on US underwent breast MRI during the study period. Of these, 135 patients had available histopathologic results and were included in the final analysis. Using a three-tier reference standard, 87 lesions (64.4%) were classified as benign, 8 lesions (5.9%) as high-risk, and 40 lesions (29.6%) as malignant.

Breast Imaging Reporting and Data System category distribution and histopathologic outcomes:

The distribution of US and MRI BI-RADS categories along with corresponding histopathologic outcomes is presented in Table 1.

Table 1: Distribution of ultrasound and MRI BI-RADS categories and corresponding histopathologic outcomes

BI-RADS Category	N	Benign	High-risk	Malignant	High-risk + Malignant rate
US 0	59	46	3	10	0.22
US 3	17	13	0	4	0.24
US 4	42	25	3	14	0.40
US 5	9	0	0	9	1.00
US 6	2	0	0	2	1.00
MRI 3	12	11	0	1	0.08
MRI 4	97	67	7	23	0.31
MRI 5	13	0	0	13	1.00

US: Ultrasonograhphy, MRI: Magnetic resonance imaging

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For the US, BI-RADS 0, 3, 4, 5, and 6 were most frequently assigned. Among BI-RADS 0 lesions (n=59), 46 were benign, 3 were high-risk, and 10 were malignant, corresponding to a combined high-risk/malignant rate of 22.0%. BI-RADS 3 lesions (n=17) included 13 benign and 4 malignant cases (23.5%). BI-RADS 4 lesions (n=42) consisted of 25 benign, 3 high-risk, and 14 malignant cases (40.5%). All BI-RADS 5 (n=9) and BI-RADS 6 (n=2) lesions were malignant (100%).

Magnetic resonance imaging classifications were predominantly BI-RADS 4 or 5. BI-RADS 3 lesions (n=12) were almost entirely benign (11 benign, 1 malignant; 8.3%), whereas BI-RADS 4 lesions (n=97) demonstrated 67 benign, 7 high-risk, and 23 malignant cases (30.9%). All BI-RADS 5 lesions (n=13) were malignant.

Across both modalities, high-risk lesions were disproportionately clustered in intermediate BI-RADS categories—especially US BI-RADS 0 and 4 and MRI BI-RADS 4—reflecting their borderline biological and imaging behavior.

Diagnostic performance of ultrasound and magnetic resonance imaging for clinically significant lesions:

For diagnostic performance analyses, high-risk and malignant lesions were evaluated together as clinically significant outcomes. When BI-RADS ≥4 was used as the biopsy threshold, US showed a sensitivity of 61.4%, specificity of 70.6%, PPV of 51.9%, and NPV of 77.9% (AUC=0.69) (Table 2).

Table 2: Diagnostic performance of ultrasound and magnetic resonance imaging for detecting clinically significant lesions (high-risk + malignant)

Metric	Ultrasound (BI-RADS ≥4 positive)	MRI (BI-RADS ≥4 positive)
Sensitivity	0.614	0.955
Specificity	0.706	0.212
Positive predictive value (PPV)	0.519	0.385
Negative predictive value (NPV)	0.779	0.900
Area under the ROC curve (AUC)	0.69	0.70

Using the same threshold, MRI demonstrated much higher sensitivity (95.5%) and NPV (90.0%), but markedly lower specificity (21.2%) and PPV (38.5%) (AUC=0.70). In other words, MRI was highly reliable in ruling out clinically significant disease but increased the number of lesions classified as biopsy-worthy, leading to lower biopsy efficiency.

Magnetic Resonance Imaging–driven Breast Imaging Reporting and Data System reclassification:

Magnetic resonance imaging reclassified BI-RADS categories in a considerable proportion of cases compared with US (Table 3). Among the 129 lesions for which both US and MRI BI-RADS categories were available, MRI changed the BI-RADS category in 53.5% of cases.Upgrade occurred in 63 lesions (48.8%) from US BI-RADS <4 to MRI BI-RADS ≥4. Of these upgraded lesions, 23.8% were high-risk or malignant. Most upgrades originated from US BI-RADS 0 and 3, indicating that MRI frequently increased the suspicion level in both incompletely evaluated and probably benign lesions. Downgrade occurred in 6 lesions (4.7%) from US BI-RADS ≥4 to MRI BI-RADS <4, and all of them were benign, suggesting that MRI may help safely reduce unnecessary biopsies in a small subset of US-suspicious lesions. Breast Imaging Reporting and Data System category remained unchanged in 60 lesions (46.5%), and the majority of malignant cases in this group were found within concordant BI-RADS 4–5 categories.

Table 3: Magnetic resonance imaging–driven breast imaging reporting and data system reclassification and corresponding histopathologic outcomes

Reclassification subgroup	N	Benign	High-risk	Malignant	High-risk + Malignant rate
US <4 → MRI ≥4 (upgrade), total	63	48	3	12	0.24
- of which originated from US BI-RADS 0	48	37	3	8	0.23
- of which originated from US BI-RADS 3	15	11	0	4	0.27
US ≥4 → MRI <4 (downgrade)	6	6	0	0	0.00
Stable category (no change between US and MRI)	60	31	3	26	0.48

US: Ultrasonograhphy, MRI: Magnetic resonance imaging

Among the 257 patients without histopathological verification, MRI rarely escalated the biopsy indication. Only 1.2% were upgraded from US BI-RADS <4 to MRI BI-RADS ≥4, while 4.3% were downgraded, and 94.5% retained the same decision threshold regarding biopsy (below or above BI-RADS 4). These findings indicate that in patients lacking tissue diagnosis, MRI

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generally reinforces rather than increases the level of suspicion.

Magnetic resonance imaging–US lesion correlation was significantly associated with the performance of second-look US (80% vs 17%, p<0.001). However, second-look US showed limited ability to predict MRI-driven upgrade (AUC=0.61; sensitivity 67%, specificity 59%), suggesting that its main purpose is verification of MRI-detected targets rather than improving malignancy prediction.

DISCUSSION

This study aimed to evaluate the impact of magnetic resonance imaging on BI-RADS category reclassification and biopsy outcomes in patients with non-mass lesions (NMLs) initially identified on ultrasonography (US). Our findings demonstrate that MRI offers a high level of diagnostic confidence in excluding clinically significant lesions, mainly reflected by its markedly increased sensitivity and high negative predictive value. However, the substantial decrease in specificity indicates that MRI tends to increase biopsy rates, and MRI-driven upgrades do not consistently translate into higher biopsy yield. These results confirm the well-known high sensitivity–low specificity paradox of MRI in breast imaging and are consistent with previous reports focusing on NMLs.[5,10]

When BI-RADS ≥4 was used as the biopsy threshold on US, the sensitivity was 61.4% and the specificity was 70.6%. This finding confirms once again that US has a limited ability to predict malignancy in NMLs. Previous studies have shown that US can lead to diagnostic uncertainty in these lesions because of operator dependence and the use of a mass-based terminology that does not fully match the imaging characteristics of non-mass findings.[11] In our study, MRI increased sensitivity to 95.5%, but specificity dropped to 21.2%, demonstrating the well-known trade-off of high sensitivity and low specificity associated with MRI. Similarly, Kim et al. reported that although MRI is highly reliable in ruling out malignancy, it also noticeably increases biopsy rates.[6]

High-risk lesions demonstrated a distinctive distribution pattern, clustering predominantly in intermediate BI-RADS categories on both US and MRI.[12] This reinforces the biological heterogeneity of these lesions and their overlap with both benign proliferative and malignant entities. Given the known association of atypical lesions with an increased long-term risk of breast cancer, management strategies should not rely solely on imaging appearance. A more individualized approach that integrates BI-RADS findings, patient risk factors and multidisciplinary decision-making may be necessary to optimize outcomes for this subgroup.[13]

Magnetic resonance imaging-driven BI-RADS reclassification affected nearly half of the cases, with 48.8% of lesions upgraded from US BI-RADS <4 to MRI BI-RADS ≥4. Nevertheless, only 23.8% of upgraded lesions were high-risk or malignant, indicating a modest diagnostic gain despite the large number of lesions escalated to biopsy recommendation. On the other hand, all MRI-driven downgrades were benign, suggesting that MRI may have the potential to safely reduce unnecessary biopsies in a small subgroup of patients; however, the limited number of downgraded cases warrants cautious interpretation. These findings align with prior studies showing the potential of MRI to improve confidence in surveillance strategies for select NMLs.[14-16]

A strong association was detected between MRI–US lesion concordance and the likelihood of performing second-look US; yet second-look US showed limited discriminatory power in predicting whether a lesion would be upgraded after MRI. This pattern suggests that second-look US serves primarily to verify the MRI-detected target on sonography rather than to refine malignancy risk. Ryu et al.[17] reached similar conclusions, emphasizing that second-look US is largely driven by cross-modality lesion visibility rather than oncologic suspicion.

Despite the clear rise in sensitivity, the AUC values of US and MRI were almost the same (0.69 vs. 0.70), showing that MRI does not greatly improve overall diagnostic discrimination compared with US. This indicates that MRI mainly strengthens confidence in ruling out malignancy rather than identifying it more accurately. Therefore, MRI can be very reassuring when negative, but when positive it is not equally effective in guiding biopsy decisions.

Although the AUC values were similar, MRI shifted the diagnostic operating point toward higher sensitivity, thereby strengthening its rule-out capability rather than improving overall discrimination performance.

Overall the clinical implications of our findings can be summarized as follows:• MRI is highly effective in ruling out malignancy in non-mass breast lesions owing to its high sensitivity and high NPV.• Because most MRI-driven upgraded lesions are benign, biopsy recommendations following upgrade should be made judiciously.• Magnetic resonance imaging-driven downgrades carry a very low risk of false negatives and may be safely incorporated into imaging surveillance strategies.• Second-look US is valuable for confirming the MRI-detected finding on US, but not for predicting malignancy.

This study has several limitations. Its retrospective design and the relatively high proportion of patients without histopathologic verification may introduce selection and verification bias. Because histopathology

was available in only a subset of patients, diagnostic performance metrics may reflect a biopsy-enriched population rather than the true diagnostic spectrum. The absence of histopathological confirmation in all patients may also have introduced verification bias, which could influence the interpretation of diagnostic performance measures. Therefore, the reported specificity and predictive values should be interpreted with caution. In addition, being a single-center study may limit the generalizability of the findings.

In conclusion, MRI significantly influences BI-RADS reclassification in non-mass breast lesions detected on ultrasound. While MRI improves diagnostic confidence in excluding malignancy due to its high sensitivity and negative predictive value, the associated reduction in specificity limits its ability to improve biopsy yield. Therefore, MRI-driven upgrades should be interpreted cautiously in clinical decision-making. On the other hand, MRI-driven downgrades may help safely reduce unnecessary biopsies in selected patients. Consequently, the role of MRI in the evaluation of non-mass breast lesions should rely on an integrated assessment that considers imaging findings together with clinical context and patient risk factors.

*Conflict of interest***:** The authors declare that they have no conflict of interest.

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REFERENCES

1. Xie Z, Xu W, Zhang H, Li L, An Y, Mao G. The value of MRI for downgrading of breast suspicious lesions detected on ultrasound. *BMC Med Imaging*. 2023;23(1):72.
2. Ertekin E, Türkdoğan F. The contribution and histopathological correlation of MRI in BI-RADS category 4 solid lesions detected by ultrasonography. *J Surg Med*. 2021;5(5):439-443.
3. Farghadani M, Soofi GJ, Sarrami AH. Is there any correlation between magnetic resonance imaging features of breast lesions of BIRADS category 4 with histopathologic results? *Adv Biomed Res*. 2017;6:7.
4. Almeida J, Gomes A, Barros T, Fahel P, Rocha M. Predictive performance of BI-RADS magnetic resonance imaging descriptors in the context of suspicious (category 4) findings. *Radiol Bras.* 2016;49(3):137-143.
5. Kim JH, Kim SY, Cui C, et al. Problem solving MRI to reduce false-positive biopsy related to breast US: Conductivity vs. DWI vs. abbreviated contrast-enhanced MRI. *J Magn Reson Imaging*. 2024;59(4):1218-1228
6. Clauser P, Krug B, Bickel H, et al. Diffusion-weighted imaging allows for downgrading mr bi-rads 4 lesions in contrast-enhanced MRI of the breast to avoid unnecessary biopsy. Clin Cancer Res. 2021;27(7):1941-1948.
7. Spick C, Bickel H, Polanec S, Baltzer P Breast lesions classified as probably benign (BI-RADS 3) on magnetic resonance imaging: A systematic review and meta-analysis. *Eur Radiol*. 2017;28(5):1919-1928.
8. Michaels AY, Birdwell RL, Chung CS, Frost EP, Giess CS. Assessment and Management of challenging BI-RADS category 3 mammographic lesions. *Radiographics.* 2016;36(5):1261-1272.
9. Milos R, Pipan F, Kalovidouri A, et al. The Kaiser score reliably excludes malignancy in benign contrast-enhancing lesions classified as BI-RADS 4 on breast MRI high-risk screening exams. *Eur Radiol.* 2020;30(11):6052-6061.
10. Gity M, Moghadam K, Jalali A, Shakiba M. Association of different mri birads descriptors with malignancy in non mass-like breast lesions. *Iran Red Crescent Med J*. 2014;16(12).
11. Lee J, Lee J, Baik S, et al. Non-mass lesions on screening breast ultrasound. *Med Ultrason.* 2016;18(4):446.
12. Rageth C, O'Flynn E, Comstock C, et al. First international consensus conference on lesions of uncertain malignant potential in the breast (b3 lesions). *Breast Cancer Res Treat*. 2016;159(2):203-213.
13. Xie Y, Zhang X. A risk prediction stratification for non-mass breast lesions, combining clinical characteristics and imaging features on ultrasound, mammography, and MRI. *Front Oncol*. 2024; 14:1337265.
14. Flowers C, O'Donoghue C, Moore D, et al. Reducing false-positive biopsies: A pilot study to reduce benign biopsy rates for bi-rads 4a/b assessments through testing risk stratification and new thresholds for intervention. *Breast Cancer Res Treat.* 2013;139(3):769-777.
15. Xie Y, Zhu Y, Chai W, et al. Downgrade BI-RADS 4A patients using nomogram based on breast magnetic resonance imaging, ultrasound, and mammography. *Front Oncol.* 2022;12:807402.
16. Meng M, Li H, Zhang M, He G, Wang L, Shen D. Reducing the number of unnecessary biopsies for mammographic BI-RADS 4 lesions through a deep transfer learning method. *BMC Med Imaging*. 2023;23(1):82.
17. Ryu H, Kim E, Park Y, Park C. The predictive value of second-look ultrasound after preoperative breast magnetic resonance imaging. *J Breast Dis*. 2015;3(2):65-70.