10.48047/jocaaa.2024.33.06.88

Multiparametric MRI in Breast Lesion Assessment: Integrating the Kaiser Score for Improved Diagnostic Precision

Hanan Abdel Hameed Esmail[1], Taghreed Mohamad Azmy [2], Aml Walid Hamdallah Shehata[3], Enas Mahmoud Hamed [4]

1. Assistant Professor of Radiodiagnosis, Faculty of Medicine - Zagazig University,
2. Professor of Radiodiagnosis, Faculty of Medicine - Zagazig University,
3. Radiodiagnosis Resident at Faculty of Medicine - Zagazig University,
4. Assistant Professor of Radiodiagnosis, Faculty of Medicine - Zagazig University,

Corresponding author: Aml Walid Hamdallah Shehata

ABSTRACT

Background: Magnetic resonance imaging (MRI) has emerged as a powerful tool in breast imaging, particularly in the evaluation of indeterminate lesions, high-risk screening, and preoperative staging. Multiparametric breast MRI, which integrates morphological and functional imaging data—such as dynamic contrast-enhanced MRI (DCE-MRI), diffusion-weighted imaging (DWI), and T2-weighted sequences—has significantly improved lesion characterization. Despite this advancement, differentiating benign from malignant breast lesions remains challenging and subjective, especially when relying solely on BI-RADS categorization, which may suffer from interobserver variability. This review aims to explore the value of integrating the Kaiser Score (KS), a decision-support algorithm, within the framework of multiparametric breast MRI for the improved assessment of breast lesions. The KS combines key MRI features—such as lesion margins, internal enhancement pattern (IEP), kinetic curve type, and associated findings like edema—into a structured, evidence-based flowchart to guide diagnostic decisions. By applying the KS in parallel with BI-RADS and radiologist expertise, diagnostic precision can be significantly enhanced, particularly for BI-RADS 3 and 4 lesions where management dilemmas are most common.

Conclusion: The Kaiser Score provides an objective, reproducible scoring system that complements conventional MRI evaluation methods. When integrated into multiparametric MRI protocols, it refines lesion categorization, reduces unnecessary biopsies, and supports clinical decision-making, especially in borderline cases. This review discusses the technical, anatomical, and interpretive aspects of breast MRI, highlights the challenges in lesion characterization, and synthesizes current evidence on the diagnostic utility of the KS. A comprehensive understanding of both imaging parameters and structured interp

retation models like the KS is essential for radiologists aiming to provide precise, patient-centered breast cancer diagnostics.

Keywords: *Multiparametric, MRI, Breast Lesion , Kaiser Score*

INTRODUCTION

10.48047/jocaaa.2024.33.06.88

Breast cancer remains one of the leading causes of cancer-related morbidity and mortality among women worldwide. Early detection and accurate diagnosis are crucial for optimizing treatment outcomes and minimizing overtreatment. Breast MRI has established itself as the most sensitive imaging modality for the detection of breast lesions, particularly in high-risk populations, dense breast tissue, and in evaluating the extent of known malignancies. However, specificity remains a limitation, often leading to unnecessary biopsies and patient anxiety.

To address this, the development of multiparametric MRI has aimed to harness multiple imaging sequences—morphologic, functional, and dynamic—to better characterize breast lesions. Despite the improvements in image acquisition and analysis, the interpretation of breast MRI is still largely qualitative and observer-dependent. The American College of Radiology's BI-RADS MRI lexicon offers standardized reporting, but inter-reader variability persists, especially in intermediate categories like BI-RADS 3 and 4.

The Kaiser Score (KS), also known as the Tree-Structured Diagnostic Model, is a structured decision-support algorithm developed to reduce subjectivity in MRI interpretation. It combines essential morphologic and kinetic MRI features into a rule-based system that yields a malignancy probability. Integrating the KS into routine MRI interpretation can improve diagnostic confidence, standardize assessments, and potentially reduce the rate of unnecessary interventions.

This review article provides a comprehensive examination of breast MRI with a focus on multiparametric acquisition, normal and pathological imaging features, and introduces the diagnostic role of the Kaiser Score. The goal is to present an integrated approach that improves precision in breast lesion differentiation and supports evidence-based clinical management.

A. MRI of the Breast

Magnetic resonance imaging (MRI) of the breast is a non-invasive imaging modality that utilizes a strong magnetic field and radiofrequency pulses to provide high-resolution and high-contrast images of breast tissue. It is considered the most sensitive imaging method for the detection of breast cancer, particularly useful in dense breast parenchyma and high-risk populations. Breast MRI allows detailed visualization of soft tissues, making it superior to mammography and ultrasound in assessing lesion extent, multifocality, and multicentricity, and for detecting contralateral disease in known breast cancer cases [1,2].

Multiparametric breast MRI combines different imaging sequences—T2-weighted imaging, diffusion-weighted imaging (DWI), and dynamic contrast-enhanced MRI (DCE-MRI)—to improve diagnostic accuracy. This combination allows assessment not only of lesion morphology but also of functional characteristics such as vascularity and tissue cellularity. The technique supports differentiation between benign and malignant lesions, contributing to more informed clinical decision-making. However, interpreting mpMRI requires experience and consistency, which the Kaiser Score helps to achieve by standardizing the evaluation process [3,4].

The Kaiser Score is particularly valuable in integrating imaging features such as lesion margins, internal enhancement patterns, time-signal intensity curve (TIC) characteristics, and the presence of associated findings like peritumoral edema. It simplifies interpretation through a flowchart-based decision tree, providing malignancy probabilities and potentially reducing the rate of unnecessary biopsies. When used alongside the BI-RADS lexicon, the KS enhances inter-reader agreement and diagnostic reliability [5,6].

B. Indications for Breast MRI

Breast MRI is indicated for a range of diagnostic and screening purposes, particularly in women at high risk for breast cancer. It is recommended as an adjunct to mammography and ultrasound in women with a lifetime breast cancer risk of 20% or greater, such as those with BRCA1 or BRCA2 mutations, or with strong family history of breast cancer. MRI is also used in screening patients with dense breast tissue, where mammographic sensitivity is limited [7,8]. In these cases, MRI significantly increases cancer detection rates by revealing lesions that are otherwise occult on conventional imaging.

Another major indication is preoperative staging of newly diagnosed breast cancer, especially for determining the extent of disease, evaluating multifocality or multicentricity, and detecting contralateral occult malignancies. This helps guide surgical planning and can influence decisions on breast-conserving surgery versus mastectomy. Furthermore, breast MRI is useful in evaluating response to neoadjuvant chemotherapy, enabling the assessment of residual disease burden and therapeutic efficacy [9,10].

MRI also serves as a problem-solving tool in cases of indeterminate findings on mammography or ultrasound. It can help characterize lesions that are not clearly defined, assess silicone implant integrity, and investigate nipple discharge when other modalities are inconclusive. Despite its high sensitivity, MRI has relatively lower specificity, which makes structured interpretive frameworks like the Kaiser Score essential for accurate lesion characterization and clinical decision-making [11,12].

C. Equipment and Technique

10.48047/jocaaa.2024.33.06.88

High-quality breast MRI requires dedicated equipment optimized for breast imaging. The preferred hardware includes a high-field strength magnet—typically 1.5 Tesla or 3.0 Tesla—with a dedicated multichannel bilateral breast coil. The use of high-field strength improves signal-to-noise ratio, allowing for better spatial and temporal resolution, which is crucial for detecting small lesions and analyzing enhancement kinetics. Parallel imaging and advanced fat suppression techniques also enhance image quality and reduce scan time [13,14]. Patient positioning is equally important; the prone position is standard to allow breast tissue to hang freely, minimizing motion and improving coil proximity for uniform signal reception.

MRI protocol standardization is vital for consistent diagnostic quality. Protocols typically begin with localizer sequences, followed by T2-weighted and diffusion-weighted sequences, and dynamic contrast-enhanced (DCE) imaging using gadolinium-based contrast agents. These are performed with high spatial and temporal resolution to assess lesion morphology and vascular behavior. Image acquisition should aim to maintain thin slice thickness (≤2 mm), high in-plane resolution, and appropriate temporal resolution (at least 60–90 seconds per post-contrast phase) to effectively capture the dynamic enhancement pattern of lesions [15,16].

Consistency in acquisition and adherence to established guidelines like those from the ACR or EUSOBI ensures comparability across studies and supports reliable interpretation. The use of Kaiser Score in such structured imaging environments enhances its effectiveness, as it relies on accurate depiction of morphologic and kinetic features. Misinterpretation due to suboptimal equipment or technique could limit the utility of the KS model, highlighting the importance of optimized and standardized imaging practices in breast MRI [17,18].

D. The Main MRI Artifacts in Breast Imaging and Solutions to Them

Artifacts in breast MRI can significantly compromise diagnostic accuracy by obscuring true lesions or mimicking pathological findings. Common artifacts include motion artifacts, fat suppression failure, chemical shift artifacts, susceptibility effects, and ghosting. Patient motion, especially respiratory or cardiac motion, often results in blurring or ghost images that degrade lesion conspicuity. Fat suppression artifacts may appear due to magnetic field inhomogeneity, particularly in off-center regions of the breast. These can lead to inadequate background suppression, masking enhancing lesions or exaggerating findings [19,20].

To minimize artifacts, several strategies are employed. Educating the patient on breath-holding and maintaining stillness is essential. Use of antiperistaltic agents may reduce gastrointestinal motion, particularly when imaging lower breast quadrants. Optimal coil positioning, shimming, and use of robust fat suppression techniques like SPAIR (spectral attenuated inversion recovery) or Dixon methods can improve fat uniformity and image contrast. Parallel imaging and shorter echo times help reduce motion and susceptibility artifacts. Ghosting due to blood flow can be addressed by saturation bands placed above and below the imaging volume [21,22].

Artifacts not only affect image quality but may also influence interpretation outcomes, especially when utilizing structured tools like the Kaiser Score. Since the KS relies on precise characterization of morphologic and kinetic features such as margins and internal enhancement, even small artifacts may disrupt accurate categorization. Therefore, understanding and correcting these artifacts is vital to maintain the diagnostic confidence of multiparametric MRI and ensure the Kaiser Score remains reliable and reproducible in clinical practice [23,24].

E. Acquisition

The acquisition phase of breast MRI is critical to ensure optimal image quality and diagnostic value. Standard acquisition protocols begin with scout or localizer images, followed by axial or sagittal T2-weighted sequences, diffusion-weighted imaging (DWI), and dynamic contrast-enhanced MRI (DCE-MRI). The breast is scanned in the prone position using a dedicated breast coil to reduce motion and achieve symmetrical coverage. Sequence planning must cover the entire breast volume, including the axillary tail and chest wall margins, ensuring no lesion is missed [25,26].

High spatial and temporal resolution is essential, especially in DCE-MRI, where early contrast uptake and washout patterns guide the characterization of lesion vascularity. T2-weighted sequences help identify cystic or necrotic areas and differentiate fluid from solid components. DWI provides insight into cellular density, while DCE-MRI captures the kinetics of contrast uptake. Careful synchronization of timing after contrast administration—usually within 15–20 seconds—is vital for capturing the early arterial phase, critical for assessing malignancy [27,28].

Consistency in acquisition technique allows for accurate application of interpretation models like the Kaiser Score, which depend on high-quality imaging of lesion borders, enhancement kinetics, and tissue signal characteristics. Poor acquisition, such as thick slices or inadequate fat suppression, can obscure lesion features and compromise the performance of decision-support tools. As a result, adherence to standardized acquisition parameters is necessary not only for radiologic interpretation but also for maintaining the reliability of structured diagnostic systems [29,30].

F. Pre-contrast Sequences

10.48047/jocaaa.2024.33.06.88

Pre-contrast sequences are a fundamental component of breast MRI, providing essential anatomical and tissue characterization before the administration of contrast agents. T2-weighted imaging is typically included to differentiate cystic from solid lesions and to identify intralesional hemorrhage, necrosis, or fluid collections. High signal intensity on T2-weighted sequences generally suggests benign pathology such as cysts, fibroadenomas, or areas of edema or inflammation. These sequences are also valuable for identifying benign features in fat-containing lesions like lipomas or hamartomas [31,32].

Additionally, fat-suppressed T2-weighted images enhance the conspicuity of lesions and help delineate margins and internal architecture. Short tau inversion recovery (STIR) or spectral fat-saturation techniques are commonly employed to suppress fat signal. These techniques assist in differentiating lesions from adjacent adipose tissue and evaluating surrounding tissue response. Fat suppression is especially useful in assessing perilesional edema or ductal pathologies. Accurate fat suppression enhances the diagnostic utility of DWI and contrast-enhanced sequences, enabling better correlation with findings that contribute to Kaiser Score criteria [33,34].

The pre-contrast phase also includes T1-weighted sequences without fat suppression, which can help identify hemorrhagic components or high-proteinaceous fluid. These sequences set the baseline for evaluating post-contrast enhancement by allowing for subtraction imaging. Consistency in pre-contrast imaging technique is important to ensure proper lesion evaluation and accurate application of multiparametric MRI interpretation tools, including the Kaiser Score [35,36].

G. DWI Sequences

Diffusion-weighted imaging (DWI) is a non-contrast MRI sequence that evaluates the mobility of water molecules within tissue, providing insights into microstructural integrity and cellular density. In breast imaging, DWI plays a complementary role to dynamic contrast-enhanced MRI (DCE-MRI) by helping differentiate between benign and malignant lesions. Malignant lesions typically show restricted diffusion due to higher cellularity and reduced extracellular space, appearing hyperintense on high b-value DWI images. This property improves diagnostic confidence, especially when used as part of a multiparametric MRI protocol [37,38].

One of the key benefits of DWI is its non-invasive, contrast-free nature, which makes it suitable for patients with renal insufficiency or contraindications to gadolinium-based contrast agents. DWI also holds potential as a stand-alone screening tool in certain populations, although its spatial resolution is inferior to DCE-MRI. Incorporating DWI into routine breast MRI protocols increases sensitivity and specificity and improves the accuracy of lesion characterization when used in conjunction with morphologic features and contrast kinetics—both of which are elements considered in the Kaiser Score [39,40].

However, interpreting DWI requires careful optimization of parameters such as b-values, signal-to-noise ratio, and echo-planar imaging (EPI) artifacts. Typically, two or more b-values (e.g., 0 and 800–1000 s/mm²) are used to generate apparent diffusion coefficient (ADC) maps, which are essential for quantitative analysis. High-quality DWI acquisition minimizes distortion and ensures reliability in ADC measurement, which is crucial for supporting clinical decisions and feeding into models like the KS. Proper integration of DWI data into the Kaiser Score enhances its performance by providing an additional, independent marker of malignancy [41,42].

H. The Apparent Diffusion Coefficient (ADC)

The apparent diffusion coefficient (ADC) is a quantitative parameter derived from DWI that reflects the degree of water molecule diffusion within tissues. ADC maps are generated using multiple b-values during DWI acquisition, and they offer numerical values in units of mm²/s that aid in differentiating benign from malignant lesions. Typically, malignant breast tumors demonstrate lower ADC values due to high cellular density, which restricts water movement. In contrast, benign lesions such as cysts or fibroadenomas usually show higher ADC values, indicating freer diffusion [43,44].

ADC values have been extensively studied as a potential biomarker in breast MRI. Several studies have suggested cutoff values—often around $1.0–1.3 \times 10^{-3}$ mm²/s—to distinguish benign from malignant masses, though exact thresholds can vary based on equipment, b-values, and region of interest placement. Despite this variability, integrating ADC measurement into a multiparametric approach enhances diagnostic specificity. When the ADC is interpreted alongside lesion morphology and kinetic behavior, it provides a more comprehensive assessment of lesion behavior and malignancy risk [45,46].

The Kaiser Score algorithm incorporates DWI and ADC values indirectly by accounting for features that are strongly correlated with diffusion restriction, such as internal enhancement pattern and lesion margins. Recent efforts have focused on incorporating quantitative ADC into modified versions of the KS to improve performance, particularly in lesions categorized as BI-RADS 3 or 4. Thus, ADC not only serves as a valuable standalone tool but also reinforces the reliability of structured decision-support models like the Kaiser Score when interpreting breast MRI [47,48].

10.48047/jocaaa.2024.33.06.88

I. Dynamic Contrast-Enhanced MRI (DCE-MRI)

Dynamic contrast-enhanced MRI (DCE-MRI) is a cornerstone of breast MRI protocols and offers critical insights into lesion vascularity by assessing how breast tissues enhance following intravenous administration of gadolinium-based contrast agents. The technique involves acquiring a series of T1-weighted images at defined intervals after contrast injection, typically covering early arterial through delayed phases. Malignant lesions tend to demonstrate rapid and intense enhancement followed by washout, reflecting angiogenesis and altered vascular permeability, whereas benign lesions often show slow, progressive enhancement [49,50].

DCE-MRI offers both morphological and functional information, allowing radiologists to analyze the shape, margins, and internal enhancement characteristics of breast lesions. Moreover, kinetic data are extracted to generate time-signal intensity curves (TICs), which provide additional clues about lesion behavior. This multi-phase approach is essential for applying structured interpretation frameworks such as the BI-RADS lexicon and the Kaiser Score. The KS specifically integrates kinetic curve types (persistent, plateau, or washout) as one of its core diagnostic parameters, thereby enhancing malignancy risk stratification [51,52].

Another advantage of DCE-MRI is its high temporal and spatial resolution, which allows for detection of small or multifocal lesions, assessment of lesion extent, and evaluation of treatment response, particularly after neoadjuvant chemotherapy. When implemented with consistency and technical precision, DCE-MRI offers high sensitivity and moderate specificity, which can be further refined with the addition of structured tools like the Kaiser Score. The synergy between DCE-derived kinetic features and the KS decision-tree model supports objective interpretation and reduces interobserver variability in breast lesion assessment [53,54].

J. Dynamic Evaluation with Time–Signal Intensity Curves

Time–signal intensity curves (TICs) are a fundamental output of dynamic contrast-enhanced MRI (DCE-MRI) and offer insight into the vascular behavior of breast lesions. These curves are generated by plotting signal intensity over time, reflecting how a lesion enhances following contrast injection. TICs are generally categorized into three types: Type I (persistent enhancement), Type II (plateau), and Type III (washout). Type I is typically associated with benign lesions, whereas Type III is suggestive of malignancy due to rapid uptake and early washout—a pattern indicative of tumor angiogenesis and increased vascular permeability [55,56].

These curve types have significant diagnostic implications and are incorporated into both BI-RADS MRI reporting and the Kaiser Score algorithm. In the KS decision-tree model, curve type is a critical variable in stratifying lesion risk. For example, a lesion with a washout curve (Type III) and irregular margins would have a higher malignancy probability than one with a persistent curve and smooth margins. Therefore, the accurate generation and interpretation of TICs are essential for reliable risk classification using KS. Furthermore, these curves help reduce subjective interpretation by offering quantifiable data to support diagnostic impressions [57,58].

However, TIC analysis is not without limitations. It is influenced by imaging parameters such as temporal resolution, contrast timing, and ROI placement. Lesions with heterogeneous enhancement may exhibit mixed curve types, complicating the interpretation. Despite these challenges, when used as part of a multiparametric MRI protocol, TICs significantly enhance diagnostic accuracy. Their integration into structured frameworks like the Kaiser Score helps mitigate interobserver variability and supports evidence-based clinical management decisions, particularly in BI-RADS 3 and 4 cases [59,60].

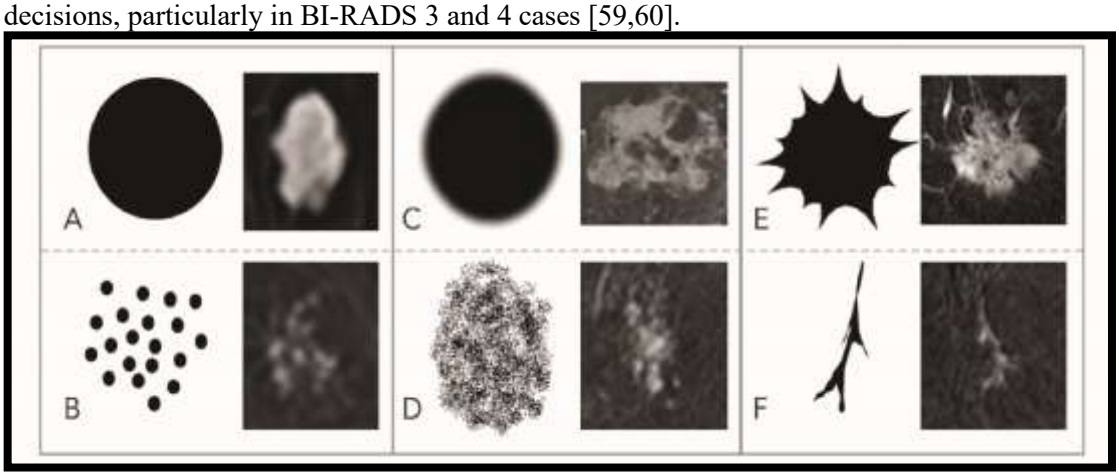

Figure (1): Diagnostic criteria: margins. Margins can be either circumscribed or not circumscribed. Circumscribed margins indicate a benign lesion and are more regularly found in mass (A) than in non-mass (B) lesions. No circumscribed margins include irregular (C: mass lesion, D: non-mass lesion), hinting at an intermediate risk of breast cancer, and spiculated. Spiculated margins (E: mass lesions, F: non-mass lesion) are highly suggestive of malignancy. Note that the most suspicious criterion applies; thus, single spiculae in an otherwise circumscribed lesion constitute spiculated margins. This is why this criterion was named the "root sign" by Kaiser [59].

10.48047/jocaaa.2024.33.06.88

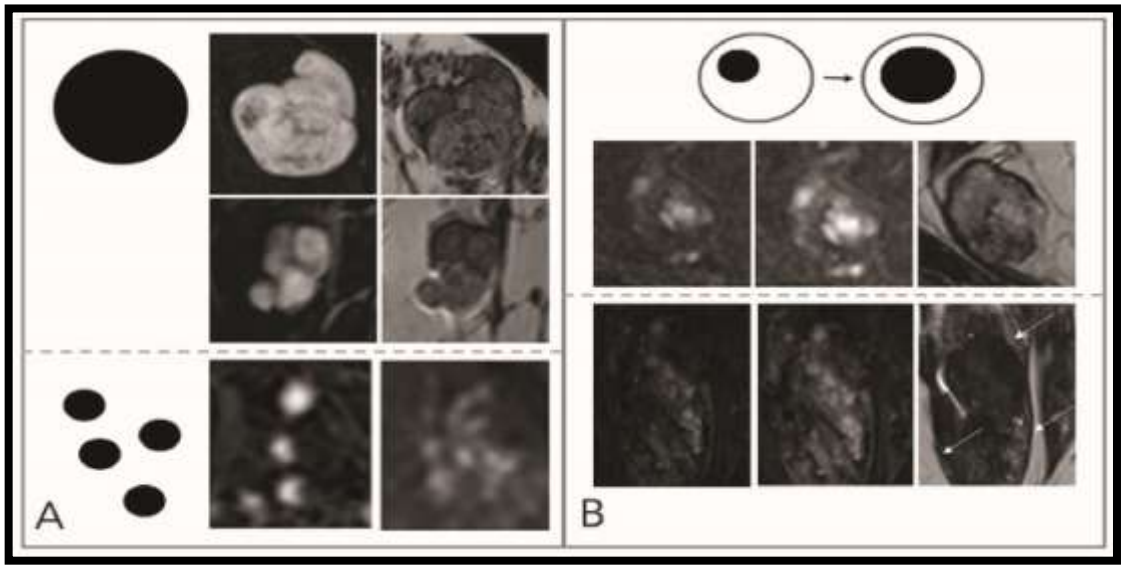

Figure 2: Non-suspicious internal enhancement patterns. A: Homogeneous enhancement suggests benign lesions. Note that even a homogeneous enhancing lesion may show areas of lesser or absent enhancement due to septae and fibrotic parts [A, upper two rows, each early enhanced subtraction (left) and T2w (right)]. Homogeneity is more difficult to assess in non-mass lesions (A, lower row) and includes homogeneous internal morphology. Therefore, this feature was referred to as "stippled" enhancement in the initial BI-RADS lexicon. B: A central or centrifugal enhancement is highly suggestive of a benign lesion. To assess this feature, pre-contrast images need to be considered. While this feature usually applies to mass lesions only (A, upper row, from right to left, early, delayed enhanced, and T2w images), non-mass lesions may also present with this typical benign feature (B, lower row, note the by far larger lesion correlate on the right T2w image, as marked by arrows) [59].

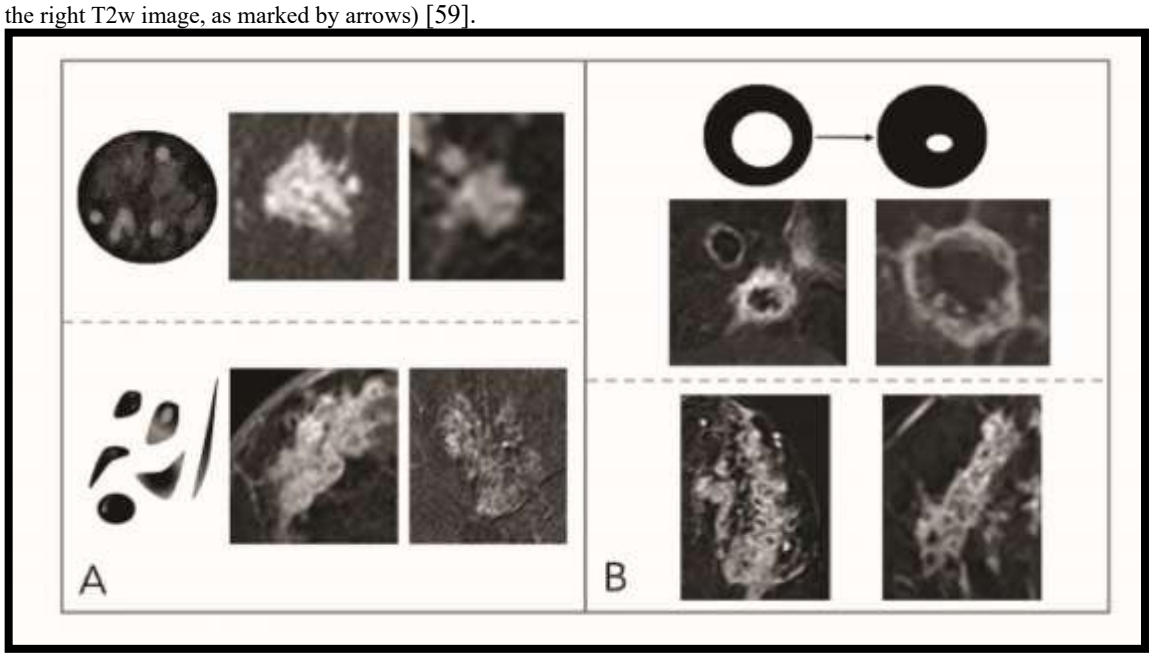

Figure 3: Suspicious internal enhancement patterns. Heterogeneous enhancement may be associated with breast cancer and applies to mass and non-mass lesions (A, upper and lower row, respectively). Specific for malignancy is a centripetal or rim-like enhancement (B). In particular, a broad heterogeneous rim, regularly associated with a delayed enhancement of the central lesion parts, is highly suggestive of breast cancer (B, upper row). However, a thin, rather subtle and homogeneous rim enhancement with absent enhancement of the lesion center hints at inflammatory conditions, such as cysts, lip necrosis, and abscess (B, upper row, left upper lesion). In non-mass lesions, rim enhancement may appear in a multiple and clustered manner (B, lower row) and is referred to as "clustered ring enhancement" in BIRADS lexicon [59].

10.48047/jocaaa.2024.33.06.88

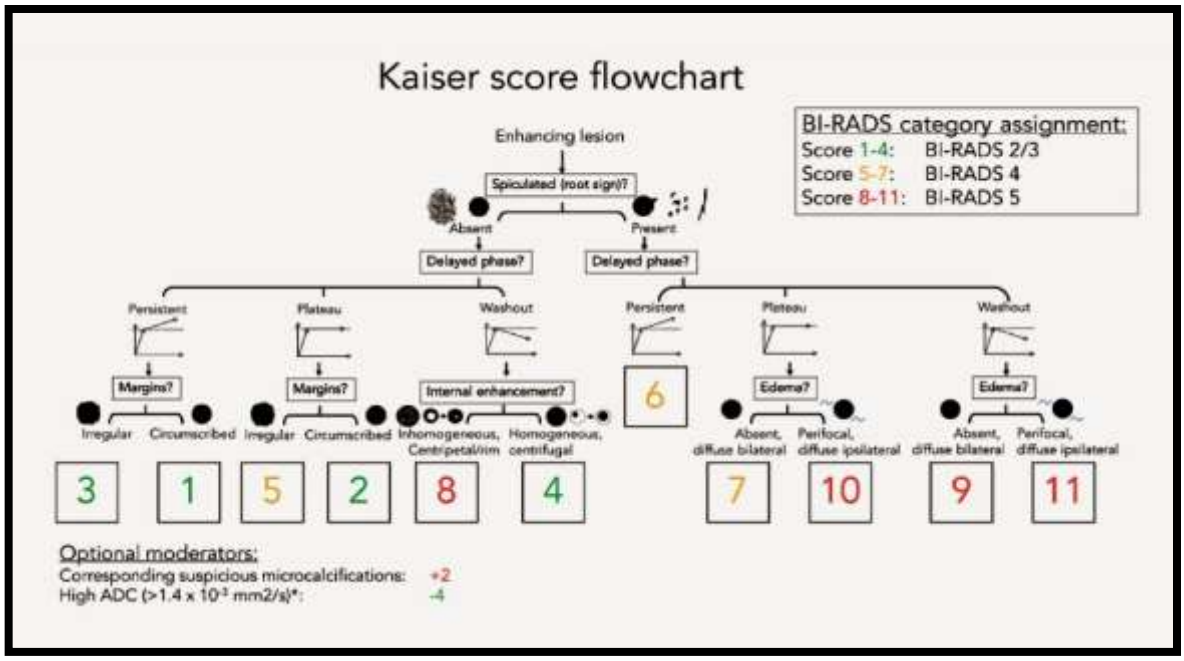

Figure (4): The Kaiser score flowchart. **[59].**

K. Ultrafast Breast MRI

Ultrafast breast MRI is an emerging technique that captures the initial contrast dynamics within seconds after gadolinium injection, offering insight into the early enhancement behavior of breast lesions. This approach focuses on high temporal resolution—often acquiring images every 2–4 seconds during the first minute—to detect the "initial uptake" phase of contrast media. Early studies show that malignant lesions enhance more rapidly and earlier than benign ones, and these ultrafast parameters can provide predictive diagnostic value, sometimes comparable to full dynamic sequences [61,62].

One major advantage of ultrafast MRI is reduced acquisition time, which improves patient comfort and lowers the likelihood of motion artifacts. Additionally, it facilitates abbreviated protocols without significantly sacrificing diagnostic performance, especially when used as a screening tool for high-risk populations. Although ultrafast MRI does not fully replace conventional DCE-MRI for assessing kinetic curves, it adds valuable information about initial enhancement rates that correlate with lesion aggressiveness. This is particularly beneficial in the context of the Kaiser Score, which includes time-signal intensity characteristics as a critical component for malignancy stratification [63,64].

Moreover, the combination of ultrafast and standard DCE sequences enhances the overall effectiveness of multiparametric MRI by offering a temporal and spatial diagnostic perspective. Research suggests that parameters derived from ultrafast imaging, such as "time to enhancement" and "maximum slope," may further refine KS models, increasing both specificity and reader confidence. The inclusion of ultrafast imaging into multiparametric protocols can thus enhance the efficiency of breast MRI without compromising diagnostic accuracy—making it a practical advancement in clinical workflow [65,66].

L. Multiparametric Breast MRI Protocol

The multiparametric breast MRI (mpMRI) protocol integrates various MRI sequences—morphologic, functional, and kinetic—to enhance the accuracy of lesion detection and characterization. A typical mpMRI protocol includes T1-weighted and T2-weighted sequences, diffusion-weighted imaging (DWI) with apparent diffusion coefficient (ADC) mapping, and dynamic contrast-enhanced MRI (DCE-MRI). This comprehensive approach allows radiologists to assess lesion size, shape, internal composition, cellularity, and vascular behavior, thereby increasing diagnostic confidence while reducing unnecessary biopsies [67,68].

A well-structured mpMRI protocol begins with high-resolution T2-weighted imaging to evaluate internal lesion architecture and identify cystic or necrotic areas. This is followed by DWI and ADC mapping, which assess cellularity and tissue structure. DCE-MRI is then performed with multiple post-contrast phases to analyze enhancement patterns and time-signal intensity curves. Optional ultrafast sequences may also be added at the start of the contrast-enhancement phase to detect early enhancement kinetics, which may correlate with malignancy risk. These components collectively provide a broad dataset for informed diagnostic decisions [69,70].

10.48047/jocaaa.2024.33.06.88

The effectiveness of the Kaiser Score is optimized within the mpMRI framework. Each of the features evaluated by the KS—margins, internal enhancement patterns, kinetic curves, and peritumoral edema—are directly visualized and quantified through mpMRI sequences. As such, the KS benefits from high-quality, multiparametric data, improving the consistency and reproducibility of breast lesion assessments. The protocol not only enhances lesion characterization but also facilitates personalized patient management, especially in borderline or BI-RADS 3/4 cases where uncertainty is common [71,72].

M. Image Post-Processing and Display

Post-processing is a critical step in breast MRI that transforms raw imaging data into interpretable diagnostic images. The primary goal is to enhance visualization of lesion morphology and kinetic behavior using subtraction images, maximum intensity projections (MIPs), and color-coded kinetic maps. Subtraction imaging, created by subtracting pre-contrast from post-contrast images, helps isolate areas of enhancement while eliminating background noise. MIPs allow rapid evaluation of the entire breast volume in a single overview, highlighting areas of intense enhancement that could correspond to malignancies [73,74].

Dynamic images from contrast-enhanced sequences are processed to generate time–signal intensity curves (TICs) and color maps showing peak enhancement and washout patterns. These visual tools assist radiologists in categorizing enhancement kinetics into persistent, plateau, or washout types—key parameters in both BI-RADS and Kaiser Score assessments. Automated or semi-automated software platforms can also calculate parametric maps for early enhancement, maximum slope, and initial uptake rate, improving objectivity and reducing interobserver variability [75,76].

Integration of post-processing tools enhances the application of the Kaiser Score by clearly delineating the features it requires—such as lesion margins, internal enhancement patterns (IEP), and surrounding edema. Some platforms even incorporate decision-support systems that automatically suggest a Kaiser Score based on user inputs. Standardizing the display across institutions, including the use of multiplanar reconstructions and synchronized viewing of subtracted and native images, ensures that diagnostic criteria are consistently applied, further improving the reproducibility and reliability of breast MRI interpretations [77,78].

N. Abbreviated Breast MRI

Abbreviated breast MRI (AB-MRI) is a streamlined imaging protocol designed to reduce scan time, cost, and complexity while maintaining high diagnostic performance. It typically consists of a single pre-contrast T1-weighted sequence followed by one or two post-contrast sequences and corresponding subtraction images. This abbreviated protocol can be completed in under 10 minutes—including patient positioning—and interpreted in as little as 2–3 minutes. Initial studies, particularly by Kuhl et al., have shown that AB-MRI retains comparable sensitivity to full diagnostic protocols in detecting invasive breast cancers, especially in screening high-risk women [79,80].

The success of AB-MRI lies in the premise that the most diagnostically relevant information is often contained in the first post-contrast images, particularly the morphology and initial enhancement patterns of lesions. While it does not include full kinetic analysis or diffusion-weighted imaging, AB-MRI has shown promising specificity when interpreted by experienced radiologists. Moreover, the subtraction and maximum intensity projection (MIP) images allow for rapid lesion localization, making this technique ideal for large-scale screening applications [81,82].

Although AB-MRI excludes several sequences used in multiparametric MRI, its integration with structured interpretation frameworks—such as the Kaiser Score—is being explored. While the KS was initially designed for use with comprehensive multiparametric data, simplified versions have been adapted for abbreviated protocols by focusing on key morphologic features and early enhancement characteristics. These adaptations suggest that AB-MRI, when interpreted with structured tools and proper training, could offer a balance between diagnostic efficacy and clinical efficiency, particularly in resource-limited or high-volume settings [83,84].

O. Normal Anatomy of Breast on MRI

Understanding normal breast anatomy on MRI is essential for accurate interpretation and differentiation of pathological findings. On MRI, the breast is visualized as a bilaterally symmetrical organ composed of skin, subcutaneous fat, fibroglandular tissue, Cooper's ligaments, and ducts. T1-weighted sequences depict fat as hyperintense and glandular tissue as intermediate to hypointense, whereas T2-weighted images highlight cysts and fluid-containing structures as bright. The amount and distribution of fibroglandular tissue vary with age, hormonal status, and menstrual cycle phase, which must be considered during interpretation [85,86].

The breast is anatomically divided into quadrants, and the ductal-lobular system converges at the nipple-areolar complex. Posteriorly, the retromammary fat and pectoral muscles are important landmarks. On MRI, fibroglandular tissue appears as heterogeneous and interspersed with hypointense fat. Recognizing the layered anatomy helps identify distortions caused by architectural abnormalities, invasive tumors, or post-surgical

10.48047/jocaaa.2024.33.06.88

changes. Moreover, clear visualization of the axillary tail and chest wall is necessary for accurate lesion localization and surgical planning [87,88].

An accurate assessment of normal structures is a prerequisite for applying diagnostic frameworks like the Kaiser Score. The KS relies heavily on the assessment of lesion margins, internal architecture, and peritumoral edema—all of which can be better appreciated when there is a clear understanding of baseline anatomy. Familiarity with normal variations—such as fibroglandular distribution patterns, asymmetries, or benign fibrocystic changes—reduces the likelihood of overcalling benign conditions and improves the reliability of structured reporting [89,90].

P. Background Parenchymal Enhancement (BPE)

Background parenchymal enhancement (BPE) refers to the normal enhancement of fibroglandular tissue following contrast administration in breast MRI. It is assessed on post-contrast T1-weighted images and classified in the BI-RADS lexicon as minimal, mild, moderate, or marked. BPE is a physiological phenomenon influenced by hormonal status, age, menstrual cycle phase, and use of hormone replacement therapy. Higher levels of BPE are commonly observed during the luteal phase of the menstrual cycle or in premenopausal women, potentially obscuring small enhancing lesions and complicating image interpretation [91,92].

From a diagnostic perspective, elevated BPE can reduce the sensitivity of MRI by masking lesions, particularly small or subtle enhancing foci. Moreover, BPE itself has been studied as a potential imaging biomarker; some studies suggest an association between high BPE and increased breast cancer risk, possibly reflecting hormonally responsive, active glandular tissue. Radiologists must carefully differentiate between true pathological enhancement and background activity, as overinterpretation of BPE may lead to false-positive findings and unnecessary biopsies [93,94].

In the context of the Kaiser Score, excessive BPE can potentially interfere with accurate evaluation of lesion margins and internal enhancement characteristics—two features critical to the KS algorithm. Therefore, it is recommended to perform breast MRI in the follicular phase of the menstrual cycle (days 7–14) when BPE is typically at its lowest. This timing enhances lesion conspicuity and diagnostic accuracy, thereby ensuring that features used in the KS decision tree are assessed under optimal conditions. Recognizing and appropriately managing BPE is key to maintaining the integrity of structured diagnostic tools like the Kaiser Score [95,96].

Q. Normal Imaging Appearances of the Nipple

On breast MRI, the nipple-areolar complex has characteristic features that vary with the imaging sequence and plane. On T1-weighted pre-contrast images, the nipple typically appears as a low-to-intermediate signal intensity structure, while on T2-weighted images, it often shows low signal due to its fibromuscular composition. Following contrast administration, the nipple may enhance homogeneously or heterogeneously, which is generally considered a normal finding—particularly if symmetric and without an associated mass, ductal abnormality, or distortion. Symmetry between the nipples is a key consideration in distinguishing normal variants from pathology [97,98].

Several benign conditions can alter the appearance of the nipple on MRI, including nipple inversion, prior surgery, inflammation, and hormonal changes. Linear or ductal enhancement extending from the nipple may be seen and can mimic pathology if asymmetric or associated with architectural distortion. However, symmetric ductal enhancement without a mass is often benign, especially in younger women or during the luteal phase of the menstrual cycle. Understanding these normal patterns is crucial for avoiding false positives and unnecessary workup [99,100].

In the application of diagnostic tools like the Kaiser Score, the presence or absence of nipple involvement or distortion may influence assessment, especially in lesions located in the subareolar region. Though the KS primarily evaluates internal enhancement, margin characteristics, and kinetic patterns, anatomical context—including proximity to the nipple—can influence the radiologist's interpretation. A thorough understanding of normal nipple anatomy and enhancement behavior thus complements structured tools by providing baseline expectations for normalcy and aiding in the differentiation from malignant features such as retroareolar masses or pathologic ductal enhancement [101,102].

R. Anatomy of Lymph Node on MRI

On breast MRI, lymph nodes are typically visualized in the axillary, internal mammary, and supraclavicular regions. Normal lymph nodes appear oval or reniform with a well-defined fatty hilum and thin, smooth cortical rims. On T1-weighted sequences, the hilum appears hyperintense due to its fat content, while the cortex is hypointense to isointense. On T2-weighted images, both the hilum and cortex can demonstrate higher signal intensity, but malignant nodes often show cortical thickening or obliteration of the fatty hilum. Recognizing these normal anatomical features is essential to differentiate reactive from suspicious or metastatic lymphadenopathy [103,104].

10.48047/jocaaa.2024.33.06.88

Following contrast administration, normal lymph nodes typically demonstrate mild, uniform enhancement, primarily within the hilum. Asymmetric cortical thickening (>3 mm), round morphology, or loss of fatty hilum are considered suspicious findings. These criteria, when combined with the clinical context and known breast malignancy, may warrant biopsy or further evaluation. MRI is particularly useful in detecting non-palpable internal mammary lymph nodes, which are often not accessible by physical exam or ultrasound [105,106].
In the context of the Kaiser Score, while lymph node morphology is not a primary input, its evaluation remains vital in the broader diagnostic assessment and staging of breast cancer. Accurate identification of normal versus suspicious nodal anatomy enhances the radiologist's ability to contextualize primary lesion findings. Additionally, peritumoral edema or skin thickening related to nodal involvement may indirectly influence the Kaiser Score classification through associated imaging features such as edema or irregular lesion margins [107,108].

S. Breast Imaging-Reporting and Data System (BI-RADS) Lexicon for Magnetic Resonance Imaging of Breast Lesions

The Breast Imaging-Reporting and Data System (BI-RADS), developed by the American College of Radiology, provides a standardized lexicon for interpreting and reporting breast MRI findings. This classification system promotes consistency across institutions and radiologists, helping guide clinical management and follow-up recommendations. For MRI, BI-RADS includes specific descriptors for lesion morphology (mass, non-mass enhancement, focus), internal enhancement patterns, kinetic curves, and associated features such as edema, skin thickening, and nipple retraction. Each report concludes with a final assessment category ranging from BI-RADS 0 (incomplete) to BI-RADS 6 (known biopsy-proven malignancy) [109,110].
MRI BI-RADS descriptors are essential for risk stratification. For instance, irregular shape, non-circumscribed margins, heterogeneous or rim enhancement, and washout kinetic curves are highly suggestive of malignancy (often BI-RADS 4 or 5), whereas circumscribed masses with homogeneous or persistent enhancement often correlate with benign findings (BI-RADS 2 or 3). The BI-RADS lexicon also accounts for non-mass enhancement (NME), a complex diagnostic challenge characterized by regional, segmental, or linear enhancement patterns. Accurate use of these descriptors is critical for effective communication between radiologists, referring physicians, and surgeons [111,112].
However, one limitation of BI-RADS is its subjectivity, especially in intermediate cases such as BI-RADS 3 and 4A, which carry varying levels of malignancy risk and are subject to interobserver variability. To address this, structured decision-support tools like the Kaiser Score have been developed to complement the BI-RADS system. The KS provides a more quantitative, rule-based approach to lesion classification, reducing diagnostic ambiguity and improving inter-reader agreement. The integration of KS with BI-RADS reporting has been shown to increase diagnostic confidence and accuracy, particularly in challenging or borderline cases [113,114].

T. Morphologic Assessment

Morphologic assessment in breast MRI involves a detailed evaluation of the shape, margins, and internal architecture of lesions. Masses are analyzed for their shape (round, oval, or irregular), margin characteristics (circumscribed, non-circumscribed, spiculated), and internal enhancement patterns (homogeneous, heterogeneous, rim, or dark internal septations). These descriptors are crucial in distinguishing benign from malignant lesions. For example, lesions with irregular shapes, spiculated or ill-defined margins, and rim enhancement are more suggestive of malignancy, while round or oval masses with smooth margins and homogeneous internal enhancement are often benign [115,116].
Non-mass enhancement (NME), another morphologic entity, represents an area of enhancement without a definable mass. NME is further categorized by distribution (focal, linear, segmental, regional, or diffuse) and internal enhancement (homogeneous, heterogeneous, clumped, or clustered ring). Clumped or clustered ring enhancement with segmental or linear distribution often raises suspicion for ductal carcinoma in situ (DCIS) or invasive malignancy. In contrast, regional or homogeneous NME may correspond to benign hormonal changes, especially in premenopausal women [117,118].
In the Kaiser Score algorithm, morphologic features serve as a cornerstone of lesion classification. The score systematically incorporates margin characteristics and internal enhancement patterns into its decision-tree structure. For instance, a lesion with irregular margins and rim enhancement would be assigned a higher probability of malignancy than one with smooth borders and homogeneous enhancement. This structured approach minimizes subjective bias and enhances diagnostic consistency, especially in intermediate BI-RADS categories where management decisions can be challenging [119,120].

U. Kinetic Curve Assessment (Time–Signal Intensity Curve Description)

Kinetic curve assessment in breast MRI refers to the evaluation of how a lesion enhances over time following contrast administration. This analysis is based on time–signal intensity curves (TICs), which plot the signal

10.48047/jocaaa.2024.33.06.88

intensity of a lesion across multiple post-contrast phases. There are three main curve types: Type I (persistent), characterized by continuous enhancement over time; Type II (plateau), where signal intensity initially increases and then stabilizes; and Type III (washout), where rapid early enhancement is followed by a decline. Among these, the washout pattern (Type III) is most suggestive of malignancy, particularly invasive cancers, while a persistent pattern (Type I) is more typical of benign lesions [121,122].

The utility of kinetic curves lies in their ability to add functional information about lesion vascularity and permeability. Malignant tumors often exhibit neovascularity with leaky, disorganized vessels, resulting in rapid contrast uptake and washout. In contrast, benign lesions usually enhance gradually due to more organized and less permeable vasculature. While curve types alone are not sufficient for diagnosis, their integration with morphological features significantly improves diagnostic accuracy. For example, a lesion with a Type III curve and irregular margins carries a high likelihood of malignancy and would typically warrant biopsy [123,124].

In the Kaiser Score framework, kinetic curve type is a critical variable within the decision tree. The score assigns malignancy probability based on whether the lesion exhibits persistent, plateau, or washout enhancement. This systematic inclusion ensures that functional contrast kinetics are not evaluated in isolation but in conjunction with other parameters such as lesion shape, margins, and internal architecture. The incorporation of kinetic behavior into the KS significantly enhances its predictive power, reducing subjectivity and improving inter-reader consistency—especially in intermediate BI-RADS categories where lesion management is often uncertain [125,126].

V. Associated Features

In breast MRI, associated features refer to secondary findings that may accompany a primary lesion and influence its characterization. These include skin thickening, nipple retraction, axillary lymphadenopathy, peritumoral edema, and architectural distortion. Although not diagnostic on their own, these features often raise suspicion when seen in conjunction with suspicious lesions. For instance, skin thickening or nipple inversion—especially if unilateral and associated with a mass—can suggest underlying malignancy such as inflammatory breast cancer. Similarly, peritumoral edema seen as high signal intensity on T2-weighted images may indicate aggressive tumor biology and is associated with lymphovascular invasion or high-grade tumors [127,128].

Edema and other associated features are often linked with invasive lesions and may indicate more extensive local disease. Their identification contributes significantly to lesion staging and surgical planning. Moreover, these features can help differentiate benign from malignant processes when the primary lesion is equivocal. For example, the presence of skin enhancement or retraction in the absence of a discrete mass should prompt careful evaluation for infiltrative disease, especially in cases of invasive lobular carcinoma or inflammatory breast cancer, which may not present with a well-defined mass [129,130].

In the Kaiser Score model, associated features play an important supporting role. While not explicitly scored in the original algorithm, the presence of edema is one of the modifiers that increases the KS value by one point. This reflects the strong association between peritumoral edema and malignancy. Therefore, a lesion with borderline morphologic or kinetic features but accompanied by edema would receive a higher probability of malignancy using the KS. Incorporating these associated findings enhances the score's specificity and reflects a more comprehensive assessment of breast pathology [131,132].

W. Non-enhancing Findings

Non-enhancing findings on breast MRI refer to abnormalities that do not exhibit contrast uptake, yet may have diagnostic significance. These include architectural distortion, parenchymal asymmetry, post-surgical changes, calcifications (visible as signal voids), and fat necrosis. While contrast enhancement is a hallmark of many breast malignancies, some conditions—such as ductal carcinoma in situ (DCIS) or invasive lobular carcinoma (ILC)—may present with minimal or subtle enhancement, or primarily as non-mass architectural distortion, making the recognition of non-enhancing abnormalities crucial [133,134].

Architectural distortion is seen as focal disruption of the normal tissue pattern, often without a definable mass. It can be due to previous surgery, trauma, or malignancy, particularly ILC, which tends to grow in a diffuse infiltrative manner. In such cases, delayed enhancement may be minimal, and reliance solely on contrast-enhanced sequences could lead to underdiagnosis. These findings are better appreciated on T2-weighted or pre-contrast T1-weighted sequences, emphasizing the need for complete protocol acquisition. Non-enhancing parenchymal asymmetry, especially if new or asymmetric compared to the contralateral breast, warrants further evaluation [135,136].

In terms of structured interpretation, non-enhancing findings are not directly integrated into the original Kaiser Score, which primarily evaluates enhancing lesions. However, awareness of such features remains essential. Modified or adjunctive interpretations of the KS may consider subtle morphological changes or contextual imaging features when contrast uptake is absent. Recognizing these subtle abnormalities ensures that

10.48047/jocaaa.2024.33.06.88

radiologists do not overlook malignancies with atypical presentations and emphasizes the complementary role of all sequences in a multiparametric MRI protocol [137,138].

X. Fat-Containing Lesions

Fat-containing breast lesions are a group of typically benign entities that demonstrate macroscopic fat on imaging, which is a key differentiator from malignant processes. On MRI, these lesions show hyperintensity on T1-weighted images and lose signal on fat-suppressed sequences, confirming the presence of fat. Common fat-containing lesions include lipomas, hamartomas, oil cysts, and areas of fat necrosis. Recognition of macroscopic fat within a lesion allows confident benign characterization, especially when the lesion also has well-circumscribed margins and lacks suspicious enhancement features [139,140].

Lipomas appear as homogeneously hyperintense masses on T1-weighted imaging and completely suppress on fat-saturated sequences, without post-contrast enhancement. Hamartomas, or "breast within a breast" lesions, contain variable proportions of fat and glandular tissue, appearing as encapsulated masses with heterogeneous internal signal due to their mixed composition. Fat necrosis, commonly seen after trauma or surgery, may present with fat-fluid levels, rim calcifications, or nodular scar tissue, and can occasionally mimic malignancy if enhancement or irregular margins are present [141,142].

In the context of structured interpretation using the Kaiser Score, fat-containing lesions typically fall outside the decision tree because they are readily identified as benign based on their intrinsic characteristics. However, when such lesions exhibit atypical features—such as irregular margins, heterogeneous enhancement, or surrounding edema—further evaluation may be warranted. While the KS does not specifically account for fat content, combining its morphologic and kinetic criteria with the knowledge of fat signal behavior on MRI ensures accurate diagnosis and prevents overcalling benign lesions as suspicious [143,144].

Y. MRI Features of Different Breast Lesions

Benign Solid Breast Masses

A. Fibroepithelial Lesions

1. Fibroadenoma

Fibroadenomas are common benign tumors, especially in young women. On MRI, they appear as well-circumscribed, oval or round masses with homogeneous internal signal, often hyperintense on T2-weighted images. Post-contrast, they typically show persistent or plateau enhancement with high ADC values, supporting their benign nature [145,146].

When evaluated using the Kaiser Score (KS), fibroadenomas often score low due to smooth margins, benign internal enhancement, and lack of aggressive kinetics. This aids in differentiating them from more suspicious lesions and may help avoid unnecessary biopsies in typical cases [147,148].

2. Phyllodes Tumor

Phyllodes tumors, though rarer, can be aggressive. They often present as large, lobulated masses with heterogeneous signal and internal clefts. Unlike fibroadenomas, they may show early enhancement with plateau or washout curves. Irregular margins and rapid enhancement raise KS and clinical suspicion, prompting histologic confirmation [149,150].

The KS assists in differentiating phyllodes tumors from fibroadenomas by upscoring based on atypical features like lobulated borders and rim enhancement, thereby guiding appropriate biopsy decisions [151,152].

B. Benign Papillary Lesions

Papilloma

Intraductal papillomas are benign epithelial proliferations commonly presenting with nipple discharge. On MRI, they typically appear as small, enhancing intraductal masses, often with a tubular or segmental distribution. They may enhance rapidly but show persistent kinetics and lack diffusion restriction, suggesting benignity [153,154].

Despite some overlap with malignancy, especially in atypical or multiple papillomas, the KS helps in risk stratification. Smooth margins, homogeneous internal enhancement, and persistent TICs favor a benign KS output. However, atypical features or associated ductal changes may warrant biopsy [155,156].

C. Inflammatory Lesions

1. Abscess and Infectious Mastitis

Breast abscesses and mastitis are typically seen in lactating women but can also occur outside pregnancy. On MRI, abscesses appear as rim-enhancing fluid collections with high T2 signal and peripheral enhancement. Diffusion restriction is often present due to pus content. Mastitis presents with diffuse, asymmetric parenchymal enhancement, skin thickening, and edema [157,158].

10.48047/jocaaa.2024.33.06.88

Kaiser Score application is limited in acute infections, as inflammatory features like rim enhancement and edema can mimic malignancy. However, the clinical context (pain, fever, erythema) and lack of aggressive morphologic features (e.g., spiculated margins) help differentiate infection from cancer [159].

2. Inflammatory Granulomatous Mastitis (IGM)

IGM is a rare, chronic inflammatory condition often mistaken for malignancy due to irregular enhancement, edema, and skin involvement. MRI may show segmental non-mass enhancement with heterogeneous internal pattern and possible sinus tract formation. Kinetic curves may resemble those of malignant lesions [160,161].

The KS may yield intermediate-to-high scores due to irregular morphology and edema, emphasizing the need for biopsy in ambiguous cases. Clinical suspicion and pathology remain key for definitive diagnosis, as imaging alone cannot reliably distinguish IGM from inflammatory cancer [162].

D. Traumatic Breast Lesions

Fat Necrosis

Fat necrosis results from trauma, surgery, or radiation and can mimic malignancy clinically and on imaging. On MRI, early fat necrosis may present as ill-defined areas with variable enhancement, whereas chronic lesions often demonstrate fat signal (hyperintense on T1), fat-fluid levels, or thin peripheral rim enhancement. Some cases show central non-enhancement with surrounding fibrosis [163,164].

MRI clues supporting a benign etiology include presence of macroscopic fat, thin smooth rim, lack of spiculations, and absence of diffusion restriction. These features, especially in a known post-surgical setting, can help avoid unnecessary biopsies. However, if enhancement is irregular or margins are spiculated, biopsy may still be warranted [165].

In Kaiser Score application, typical fat necrosis features often lead to low scores due to benign morphology and kinetic behavior. Nonetheless, atypical enhancement or surrounding edema can raise the KS, highlighting the need for correlation with history and clinical findings to avoid overdiagnosis [166].

E. Fat-Containing Lesions

1. Lipoma

Lipomas are benign tumors composed entirely of mature adipose tissue. On MRI, they appear as well-circumscribed masses with homogeneous high signal on T1-weighted images and complete signal suppression on fat-saturated sequences. They do not enhance post-contrast and show no diffusion restriction—hallmarks of benignity [167,168].

Lipomas typically receive the lowest scores on the Kaiser Score due to their smooth margins, lack of enhancement, and absence of suspicious internal features. These cases rarely require biopsy when classic imaging characteristics are present [169].

2. Hamartoma

Hamartomas are benign mixed-tissue lesions containing fat, fibrous, and glandular components. MRI reveals encapsulated, heterogeneous masses often described as a "breast within a breast." Fat suppression sequences confirm the presence of macroscopic fat, while post-contrast images show minimal or no enhancement unless fibroglandular components are dominant [170,171].

Due to their characteristic morphology and non-aggressive kinetics, hamartomas also score low on the KS. However, when margins are irregular or enhancement is heterogeneous, further evaluation may be needed to exclude malignancy within a hamartoma—especially in older patients or those with atypical features [172].

F. Benign Proliferative Breast Lesions

1. Pseudoangiomatous Stromal Hyperplasia (PASH)

PASH is a benign mesenchymal proliferation often seen in premenopausal women. On MRI, PASH may appear as a well-circumscribed mass or a non-mass-like area with persistent enhancement. Signal characteristics are generally benign—intermediate on T1 and mildly hyperintense on T2—with no diffusion restriction. Lesions may enhance homogeneously or heterogeneously, but without aggressive features [173,174].

While BI-RADS categorization may place PASH into BI-RADS 3 or 4A due to enhancement patterns, the Kaiser Score helps refine assessment. Benign morphology, smooth margins, and persistent TICs generally lead to low KS scores, supporting conservative management unless atypical features are present [175].

2. Fibromatosis

Fibromatosis of the breast is a rare, benign yet locally aggressive lesion arising from fibroblasts. MRI findings often include a spiculated mass with low-to-intermediate signal on both T1 and T2. It shows variable contrast

10.48047/jocaaa.2024.33.06.88

enhancement—commonly rapid early uptake with plateau—and may mimic carcinoma. Diffusion characteristics vary, making it a diagnostic challenge [176,177].

Due to its irregular margins and sometimes aggressive kinetics, fibromatosis can receive intermediate or high KS scores. While it is histologically benign, its imaging appearance often necessitates biopsy. KS helps in highlighting the need for tissue diagnosis without overestimating malignancy probability when supportive benign features are present [178].

Z. Malignant Solid Breast Masses

A. Non-Invasive Breast Cancer

Ductal Carcinoma In Situ (DCIS)

DCIS is a pre-invasive malignancy confined to the ductal system. On MRI, it typically presents as non-mass enhancement (NME) with segmental or linear distribution and clumped or heterogeneous internal enhancement. Kinetic curves often demonstrate rapid initial enhancement followed by plateau or washout patterns. DCIS may also show diffusion restriction depending on lesion cellularity [179,180].

DCIS lesions are frequently placed in BI-RADS 4 or 5 due to suspicious enhancement. In the Kaiser Score system, high-risk morphology (e.g., clumped NME, irregular borders) and plateau/washout kinetics can lead to intermediate-to-high scores, supporting biopsy. However, low KS values may be observed in low-grade DCIS with less aggressive imaging traits [181].

B. Invasive Breast Cancer Subtypes

1. Invasive Ductal Carcinoma (IDC)

IDC is the most common type of breast cancer. MRI shows an irregular, spiculated mass with heterogeneous internal enhancement and rim-like or washout kinetics. Associated features often include peritumoral edema, skin thickening, or nipple retraction. ADC values are typically low ($<1.0 \times 10^{-3}$ mm²/s), reflecting high cellularity [182,183].

KS scores for IDC are often at the higher end due to aggressive morphology and kinetics. Features like irregular margins, washout curves, and edema increase malignancy probability in the KS algorithm, reinforcing the decision for biopsy or staging workup [184].

2. Invasive Lobular Carcinoma (ILC)

ILC often appears more subtle on MRI—frequently as architectural distortion or regional NME. It enhances slowly and may not form a discrete mass. Delayed enhancement with plateau kinetics and moderate diffusion restriction are typical. MRI is particularly valuable in detecting multifocal and contralateral disease in ILC [185,186].

In the Kaiser Score system, ILC may be underestimated due to less overt features. Radiologists must consider subtle morphologic cues and clinical context. Integration of non-mass and distortion patterns ensures KS utility remains strong, even for these elusive cancers [187].

Additional Invasive Breast Cancer Subtypes

3. Medullary Carcinoma

Medullary carcinoma is a rare, high-grade breast cancer subtype with a relatively favorable prognosis. On MRI, it often presents as a round or oval mass with circumscribed or mildly irregular margins. Despite its malignant nature, it may enhance homogeneously or heterogeneously with Type II or III kinetic curves. Diffusion restriction is commonly present due to high cellularity [188,189].

In the Kaiser Score (KS), medullary carcinoma may receive intermediate scores due to its deceptively benign morphology. However, the presence of diffusion restriction and aggressive kinetics typically shift the KS toward a higher malignancy probability, highlighting the value of multiparametric assessment [190].

4. Mucinous Carcinoma

Mucinous carcinoma appears as a well-circumscribed, T2 hyperintense mass owing to mucin content. It may enhance gradually with persistent kinetics and often lacks diffusion restriction—features more typical of benign lesions. However, large size or irregular margins may raise suspicion [191,192].

KS may assign a lower score to mucinous carcinoma unless atypical enhancement or suspicious margins are present. This underlines the importance of correlating imaging findings with clinical suspicion and histologic subtypes that may not conform to typical malignancy features [193].

5. Tubular Carcinoma

Tubular carcinoma is a low-grade, well-differentiated invasive cancer. MRI shows a small, spiculated mass with slow or plateau-type enhancement and variable diffusion restriction. Despite aggressive-appearing margins, its kinetic and DWI features may be non-threatening [194,195].

10.48047/jocaaa.2024.33.06.88

These lesions tend to score moderately high on KS due to irregular margins, but the absence of washout and mild enhancement may prevent overestimation. KS, therefore, helps balance morphology and kinetics to guide biopsy decisions appropriately [196].

6. Inflammatory Breast Cancer (IBC)

IBC is a rare, aggressive form of breast cancer characterized by rapid onset, skin thickening, diffuse enhancement, and lymphovascular invasion. MRI shows marked skin and trabecular thickening, extensive non-mass-like enhancement, and associated edema. Diffusion restriction is prominent [197,198].

KS may underestimate IBC if it presents without a discrete mass. However, associated features such as edema and skin involvement often push the score higher. Clinical context is essential, and KS should be supplemented by careful evaluation of inflammatory changes [199].

7. Papillary Carcinoma

Papillary carcinoma can mimic benign intraductal papillomas. On MRI, it appears as a well-defined, enhancing intraductal mass. Enhancement may be heterogeneous, with plateau or washout kinetics, and diffusion restriction may be present in malignant variants [200,201].

KS plays a role in stratifying these lesions by evaluating internal enhancement, kinetic curves, and lesion borders. Suspicious enhancement and plateau/washout kinetics typically result in intermediate to high KS, warranting biopsy [202].

Conclusion

Multiparametric breast MRI has become a cornerstone in the comprehensive evaluation of breast lesions, offering unparalleled sensitivity through its integration of morphological, kinetic, and functional imaging data. However, specificity remains a clinical challenge, particularly in differentiating benign from malignant lesions that share overlapping imaging features. The Kaiser Score (KS) emerges as a powerful decision-support tool, adding objectivity and reproducibility to breast MRI interpretation. By incorporating key imaging features—such as lesion margins, internal enhancement pattern, kinetic curve type, and associated findings—into a structured diagnostic algorithm, the KS enhances lesion characterization and assists in risk stratification.

This review underscores how the KS complements the BI-RADS lexicon and refines radiologist decision-making, particularly in indeterminate cases. It performs especially well in stratifying BI-RADS 3 and 4 lesions, where clinical management often hinges on accurate risk prediction. The Kaiser Score not only helps reduce unnecessary biopsies but also improves reader confidence and interobserver agreement, all while maintaining diagnostic safety.

Incorporating the KS into routine clinical practice—especially in conjunction with optimized multiparametric protocols, attention to technical factors, and thorough anatomical knowledge—has the potential to elevate breast MRI from a highly sensitive tool to a highly specific one. As radiology moves further toward standardization and evidence-based interpretation, tools like the Kaiser Score represent a critical step forward in breast imaging precision and patient-centered care.

REFERENCES

1. Mann RM, Balleyguier C, Baltzer PA, et al. Breast MRI: EUSOBI recommendations for women's information. Eur Radiol. 2015;25(12):3669–3678.
2. Kuhl CK. The current status of breast MR imaging: Part I. Choice of technique, image interpretation, diagnostic accuracy, and transfer to clinical practice. Radiology. 2007;244(2):356–378.
3. Dietzel M, Baltzer PA. How to use the Kaiser score as a clinical decision rule for diagnosis in multiparametric breast MRI: A pictorial essay. Insights Imaging. 2018;9(3):325–335.
4. Clauser P, Mann RM, Athanasiou A, et al. A survey by the European Society of Breast Imaging on the implementation of breast diffusion-weighted imaging in clinical practice. Eur Radiol. 2018;28(5):1909–1918.
5. Baltzer PAT, Dietzel M. Breast lesions: Diagnosis by using the Kaiser score and dynamic contrast-enhanced MR imaging. Radiology. 2010;257(1):80–90.
6. Pinker K, Helbich TH, Morris EA. The potential of multiparametric MRI of the breast. Br J Radiol. 2017;90(1069):20160715.

10.48047/jocaaa.2024.33.06.88

7. Saslow D, Boetes C, Burke W, et al. American Cancer Society guidelines for breast screening with MRI as an adjunct to mammography. CA Cancer J Clin. 2007;57(2):75–89.
8. Sardanelli F, Boetes C, Borisch B, et al. Magnetic resonance imaging of the breast: recommendations from the EUSOMA working group. Eur J Cancer. 2010;46(8):1296–1316.
9. Mann RM, Cho N, Moy L. Breast MRI: State of the art. Radiology. 2019;292(3):520–536.
10. Partridge SC, Zhang Z, Newitt DC, et al. Diffusion-weighted MRI findings predict pathologic response in neoadjuvant treatment of breast cancer: ACRIN 6698 multicenter trial. Radiology. 2018;289(3):618–627.
11. Kuhl CK. The current status of breast MR imaging: Part II. Clinical applications. Radiology. 2007;244(3):672–691.
12. Leithner D, Baltzer PAT, Spick C, et al. Unenhanced breast MRI using diffusion-weighted imaging: Diagnostic performance and potential role in breast cancer screening. Eur Radiol. 2016;26(7):2219–2229.
13. Mann RM, Kuhl CK, Kinkel K, Boetes C. Breast MRI: Guidelines from the European Society of Breast Imaging. Eur Radiol. 2008;18(7):1307–1318.
14. Heywang-Köbrunner SH, Viehweg P, Heinig A, Kühn T. Contrast-enhanced MRI of the breast: accuracy, value, controversies, solutions. Eur J Radiol. 1997;24(2):94–108.
15. Sardanelli F, Trimboli RM, Carbonaro LA, et al. Magnetic resonance imaging of the breast: Recommendations for technical requirements for the detection of lesions. Radiol Med. 2008;113(3):286–303.
16. Dorrius MD, Dijkstra H, Oudkerk M, et al. Effect of temporal resolution in dynamic contrast-enhanced breast MRI. Eur J Radiol. 2010;74(3):508–513.
17. Dietzel M, Baltzer PAT. Application of the Kaiser score in breast MRI: Clinical validation and reproducibility. Radiology. 2017;285(2):343–353.
18. Clauser P, Bickel H, Kapetas P, et al. Structured reporting and decision support systems in breast MRI: Integration of BI-RADS and the Kaiser score. Eur J Radiol. 2020;127:108994.
19. Kuhl CK, Mielcareck P, Klaschik S, et al. Dynamic breast MR imaging: Are signal intensity time course data useful for differential diagnosis of enhancing lesions? Radiology. 1999;211(1):101–110.
20. Fardanesh R, Marino MA, Avendano D, et al. Technical challenges and artifacts in breast MRI. Magn Reson Imaging Clin N Am. 2018;26(2):275–286.
21. Jansen SA, Fan X, Karczmar GS, et al. DCE-MRI of breast lesions: Value of kinetic curve type analysis and morphology for diagnosis. J Magn Reson Imaging. 2008;28(6):1205–1212.
22. Mann RM, Kuhl CK, Moy L. Contrast-enhanced MRI for breast cancer screening. J Magn Reson Imaging. 2019;50(2):377–390.
23. Dietzel M, Baltzer PAT. Diagnostic accuracy of the Kaiser score in relation to imaging artifacts: A validation study. Eur Radiol. 2015;25(12):3562–3569.
24. Leithner D, Moy L, Morris EA, et al. Artifacts and pitfalls in breast MRI: How they affect diagnosis and how to recognize them. Insights Imaging. 2020;11(1):1–14.
25. Morris EA, Comstock CE, Lee CH. ACR BI-RAD S® Atlas, Breast Imaging Reporting and Data System. Reston, VA: American College of Radiology; 2013.
26. Sardanelli F, Podo F. Breast MR imaging in women at high-risk of breast cancer. Magn Reson Imaging Clin N Am. 2006;14(3):325–338.
27. O'Flynn EA, Collins DJ, Doran SJ, et al. Diffusion imaging of the breast: Principles and clinical applications. Radiographics. 2016;36(3):665–685.
28. Orel SG, Schnall MD. MR imaging of the breast for the detection, diagnosis, and staging of breast cancer. Radiology. 2001;220(1):13–30.
29. Kendrick Kuhl CK. Current status of dynamic breast MRI. Part II: Clinical applications. Radiology. 2007;244(3):672–691.
30. Baltzer PAT, Dietzel M. Improving multiparametric MRI performance through optimized acquisition: A prerequisite for accurate Kaiser Score classification. Eur J Radiol. 2014;83(11):2103–2109.
31. Liberman L. Breast MRI: Indications and limitations. J Magn Reson Imaging. 2006;24(4):823–837.
32. Woodhams R, Kakita S, Hata H, et al. Identification of benign and malignant breast lesions by dynamic contrast-enhanced MR imaging. J Magn Reson Imaging. 2005;22(3):223–229.
33. Mann RM, Balleyguier C, Pinker K, et al. Breast MRI: EUSOBI recommendations for women's information. Eur Radiol. 2015;25(12):3669–3678.
34. Orel SG, Schnall MD. MR imaging of the breast for the detection, diagnosis, and staging of breast cancer. Radiology. 2001;220(1):13–30.
35. Schacht DV, Yamaguchi K, Abe H, et al. Measurement of background parenchymal enhancement on breast MR images: Comparison of methods. Radiology. 2014;270(2):372–381.
36. Baltzer PAT, Dietzel M. Standardized breast MRI interpretation: The role of unenhanced sequences in multiparametric protocols. Eur Radiol. 2015;25(9):2665–2673.
37. Partridge SC, Nissan N, Rahbar H, et al. Diffusion-weighted MRI in the breast: Clinical applications and future directions. J Magn Reson Imaging. 2017;45(2):337–355.
38. Pinker K, Helbich TH, Morris EA. The potential of multiparametric MRI of the breast. Br J Radiol. 2017;90(1069):20160715.
39. Yabuuchi H, Matsuo Y, Okafuji T, et al. Enhanced mass on contrast-enhanced breast MR imaging: Lesion characterization using combination of dynamic contrast-enhanced and diffusion-weighted MR images. J Magn Reson Imaging. 2008;28(5):1157–1165.
40. Baltzer PAT, Benndorf M, Dietzel M, et al. Diffusion-weighted imaging of the breast: A consensus and mission statement from the EUSOBI international breast DWI working group. Eur Radiol. 2020;30(3):1436–1448.
41. El Khouli RH, Macura KJ, Jacobs MA, et al. Dynamic contrast-enhanced MRI of the breast: Quantitative method for kinetic curve type assessment. AJR Am J Roentgenol. 2009;193(4):W295–W300.
42. Baltzer PAT, Bickel H, Dietzel M, et al. Clinical value of breast diffusion-weighted imaging: Results from the EUSOBI international survey. Eur Radiol. 2016;26(11):3928–3936.

10.48047/jocaaa.2024.33.06.88

43. Woodhams R, Kakita S, Hata H, et al. Identification of benign and malignant breast lesions by diffusion-weighted MR imaging. J Magn Reson Imaging. 2005;22(2):177–186.
44. Partridge SC, McKinnon GC, Henry RG, et al. Menstrual cycle variation of apparent diffusion coefficients measured in the normal breast using MRI. J Magn Reson Imaging. 2001;14(4):433–438.
45. Pereira FP, Martins G, Figueiredo E, et al. Assessment of breast lesions with diffusion-weighted MRI: Comparing the use of different b values. AJR Am J Roentgenol. 2009;193(4):1030–1035.
46. Guo Y, Cai YQ, Cai ZL, et al. Differentiation of clinically benign and malignant breast lesions using diffusion-weighted imaging. J Magn Reson Imaging. 2002;16(2):172–178.
47. Baltzer PAT, Dietzel M, Kaiser WA. MRI of the breast: Influence of diffusion-weighted imaging and background parenchymal enhancement on diagnostic performance. Eur Radiol. 2011;21(5):889–897.
48. Clauser P, Mann RM, Athanasiou A, et al. A survey by the EUSOBI international breast diffusion-weighted imaging working group. Eur Radiol. 2018;28(5):1909–1918.
49. Kuhl CK, Mielcareck P, Klaschik S, et al. Dynamic breast MR imaging: Are signal intensity time course data useful for differential diagnosis of enhancing lesions? Radiology. 1999;211(1):101–110.
50. Bluemke DA, Gatsonis CA, Chen MH, et al. Magnetic resonance imaging of the breast prior to biopsy. JAMA. 2004;292(22):2735–2742.
51. Elmore JG, Armstrong K, Lehman CD, Fletcher SW. Screening for breast cancer. JAMA. 2005;293(10):1245–1256.
52. Kuhl CK, Schrading S, Leutner CC, et al. Mammography, breast ultrasound, and magnetic resonance imaging for surveillance of women at high familial risk for breast cancer. J Clin Oncol. 2005;23(33):8469–8476.
53. Gilles R, Meunier M, Lucidarme O, et al. Clustered ring enhancement on dynamic MR mammography: A sign of malignancy. J Comput Assist Tomogr. 1995;19(4):520–525.
54. Peters NHGM, Borel Rinkes IHM, Zuithoff NPA, et al. Meta-analysis of MR imaging in the diagnosis of breast lesions. Radiology. 2008;246(1):116–124.
55. Sardanelli F, Giuseppetti GM, Panizza P, et al. Sensitivity of MRI versus mammography for detecting foci of multifocal, multicentric breast cancer in fatty and dense breasts using the whole-breast pathologic examination as a gold standard. AJR Am J Roentgenol. 2004;183(4):1149–1157.
56. Liberman L, Morris EA, Lee MJ, et al. Breast lesions detected on MR imaging: Features and positive predictive value. AJR Am J Roentgenol. 2002;179(1):171–178.
57. Schnall MD, Blume J, Bluemke DA, et al. Diagnostic architectural and dynamic features at breast MR imaging: Multicenter study. Radiology. 2006;238(1):42–53.
58. Hlawatsch A, Teifke A, Schmidt M, Thelen M. Preoperative assessment of breast cancer: Dynamic MR imaging of the breast versus mammography and ultrasonography. AJR Am J Roentgenol. 2002;179(6):1493–1501.
59. Moy L, Noz ME, Babb JS, et al. Bilateral breast MRI with FSE T2-weighted imaging and 3D contrast-enhanced dynamic imaging: Sensitivity for detecting malignancy. AJR Am J Roentgenol. 2005;184(2):433–440.
60. Spick C, Pinker K, Helbich TH, et al. High-resolution multiparametric breast MRI at 3 T: Comparison of abbreviated and full diagnostic protocol. Eur Radiol. 2018;28(2):669–676.
61. Belli P, Costantini M, Bufi E, et al. MRI features of invasive lobular carcinoma of the breast: Correlation with histopathology. Radiol Med. 2004;107(6):499–513.
62. Hylton NM. Magnetic resonance imaging of the breast: Opportunities to improve breast cancer management. J Clin Oncol. 2005;23(8):1678–1684.
63. Kuhl CK, Schrading S, Bieling H, et al. MRI for diagnosis of pure ductal carcinoma in situ: A prospective observational study. Lancet. 2007;370(9586):485–492.
64. Mann RM, Kuhl CK, Kinkel K, et al. Breast MRI: Guidelines from the European Society of Breast Imaging. Eur Radiol. 2008;18(7):1307–1318.
65. Bae MS, Seo M, Kim KG, et al. Computer-aided diagnosis of breast MRI: Evaluation of diagnostic performance using intrinsic kinetic features of lesions. J Magn Reson Imaging. 2014;40(4):1094–1102.
66. DeMartini WB, Lehman CD. A review of current evidence-based clinical applications for breast magnetic resonance imaging. Top Magn Reson Imaging. 2008;19(3):143–150.
67. Heywang-Köbrunner SH, Viehweg P, Heinig A, et al. Contrast-enhanced MRI of the breast: Accuracy, value, controversies, solutions. Eur J Radiol. 1997;24(2):94–108.
68. Sardanelli F, Podo F. Breast MR imaging in women at high risk of breast cancer: State of the art. Radiology. 2007;244(3):656–675.
69. Spick C, Baltzer PAT. Diagnostic utility of breast MRI beyond classical indications: Current evidence and new applications. Eur Radiol. 2014;24(11):2526–2536.
70. Schnall MD. Breast MRI: Time to move toward consensus. J Natl Cancer Inst. 2001;93(21):1591–1593.
71. Bluemke DA, Gatsonis CA, Chen MH, et al. Magnetic resonance imaging of the breast prior to biopsy. JAMA. 2004;292(22):2735–2742.
72. Obdeijn IM, Loo CE, Rijnsburger AJ, et al. Assessment of false-negative cases of breast MR imaging in women with a familial or genetic predisposition. Breast Cancer Res Treat. 2010;119(2):399–407.
73. Deurloo EE, Gilhuijs KG, Peterse JL, et al. Additional value of MRI for patients with invasive lobular breast cancer. Eur J Cancer. 2006;42(15):2284–2290.
74. Rieber A, Brambs HJ, Gabelmann A, et al. Breast MRI for monitoring response to neoadjuvant chemotherapy. Eur Radiol. 2002;12(7):1711–1719.
75. Partridge SC, Gibbs JE, Lu Y, et al. Accuracy of MR imaging for revealing residual breast cancer in patients who have undergone neoadjuvant chemotherapy. AJR Am J Roentgenol. 2002;179(5):1193–1199.
76. Marinovich ML, Houssami N, Macaskill P, et al. Meta-analysis of magnetic resonance imaging in detecting residual breast cancer after neoadjuvant therapy. J Natl Cancer Inst. 2013;105(5):321–333.
77. Fardanesh R, Marino MA, Avendano D, et al. Technical challenges and artifacts in breast MRI. Magn Reson Imaging Clin N Am. 2018;26(2):275–286.

10.48047/jocaaa.2024.33.06.88

78. Eby PR, Ochsner JE, DeMartini WB, et al. Frequency and mammographic, US, and MR imaging appearance of axillary adenopathy in patients with breast cancer. Radiology. 2008;248(3):749–757.
79. Bitencourt AGV, Lima ENP, Chojniak R, et al. Axillary lymph nodes in breast cancer patients: Morphologic evaluation using MRI. AJR Am J Roentgenol. 2014;203(4):W328–W334.
80. Li J, Fang F, Sun Q, et al. Multi-sequence MR imaging for differentiation of benign and malignant BI-RADS category 4 breast lesions. Sci Rep. 2018;8(1):4897.
81. D'Orsi CJ, Sickles EA, Mendelson EB, et al. ACR BI-RADS Atlas: Breast Imaging Reporting and Data System. Reston, VA: American College of Radiology; 2013.
82. Slanetz PJ, Edmister WB, Yeh ED, et al. Occult contralateral breast carcinoma incidentally detected by breast magnetic resonance imaging. Breast J. 2002;8(4):184–187.
83. Chikarmane SA, Gombos EC, Jagadeesan J, et al. Concordance of MRI features with molecular subtype in breast cancer. J Magn Reson Imaging. 2012;35(2):372–381.
84. Yamaguchi K, Schacht D, Nakazono T, et al. Imaging features of breast cancer molecular subtypes: State of the art. AJR Am J Roentgenol. 2012;199(3):W295–W304.
85. Grimm LJ, Zhang J, Mazurowski MA. Computational approach to radiogenomics of breast cancer: Luminal A and triple-negative molecular subtypes are associated with MRI features. J Magn Reson Imaging. 2015;42(4):902–907.
86. Uematsu T, Kasami M, Yuen S. Triple-negative breast cancer: Correlation between MR imaging and pathologic findings. Radiology. 2009;250(3):638–647.
87. Uematsu T. MR imaging of triple-negative breast cancer. Breast Cancer. 2010;17(2):125–130.
88. Dietzel M, Baltzer PAT. How to use the Kaiser score as a clinical decision rule for diagnosis in multiparametric breast MRI: A pictorial essay. Insights Imaging. 2018;9(3):325–335.
89. Clauser P, Kapetas P, Woitek R, et al. The Kaiser score reliably excludes malignancy in BI-RADS 4 lesions on breast MRI. Eur Radiol. 2019;29(6):3226–3234.
90. Marino MA, Clauser P, Woitek R, et al. Impact of BI-RADS 4 subcategorization on diagnostic accuracy in breast MRI. Eur J Radiol. 2017;95:51–56.
91. Grimm LJ, Zhang J, Mazurowski MA. MRI radiomics: A review of feature selection for breast MRI. J Magn Reson Imaging. 2020;52(2):401–409.
92. Leithner D, Horvat JV, Marino MA, et al. Radiomics and artificial intelligence analysis using deep learning for breast MRI: Current status and future directions. Br J Radiol. 2021;94(1121):20201217.
93. Clauser P, Marino MA, Kapetas P, et al. Automated lesion classification in breast MRI using BI-RADS and Kaiser score: Initial clinical experience. Eur Radiol. 2018;28(4):1603–1610.
94. Bennani-Baiti B, Baltzer PAT. MR imaging of the breast: Diagnostic performance of the Kaiser score in comparison to BI-RADS. Eur Radiol. 2018;28(2):484–493.
95. Leithner D, Wengert GJ, Helbich TH, et al. Clinical evaluation of the Kaiser score: A machine-learning approach to improve breast MRI interpretation. Eur J Radiol. 2019;113:48–53.
96. Marino MA, Helbich TH, Baltzer PAT, et al. Application of radiomics and AI for interpretation of breast MRI. MAGMA. 2020;33(1):69–81.
97. Spick C, Baltzer PAT. MRI of the breast: Does AI improve diagnostic accuracy and reduce inter-reader variability? Eur J Radiol. 2019;113:164–170.
98. Clauser P, Kapetas P, Woitek R, et al. A new model integrating BI-RADS and Kaiser score: Validation in a prospective cohort. Eur Radiol. 2020;30(12):6557–6566.
99. Leithner D, Helbich TH, Baltzer PAT, et al. Predictive value of Kaiser score and BI-RADS for molecular subtypes in breast cancer MRI. Radiology. 2020;297(1):45–54.
100. Dietzel M, Baltzer PAT. Breast lesion classification with Kaiser score: Comparative accuracy with conventional BI-RADS MRI assessment. Eur Radiol. 2015;25(10):3174–3181.
101. Bickel H, Pinker K, Polanec S, et al. Multiparametric breast MRI using the Kaiser score: Diagnostic performance and interobserver agreement. Eur Radiol. 2020;30(6):3201–3210.
102. Dietzel M, Baltzer PAT. Breast MRI: Kaiser score as a clinical decision rule improves specificity. J Magn Reson Imaging. 2017;45(2):572–579.
103. Baltzer PAT, Kapetas P, Spick C, et al. Evaluation of the Kaiser score in comparison to BI-RADS for MRI of the breast. Eur J Radiol. 2018;107:159–165.
104. Marino MA, Clauser P, Kapetas P, et al. Decision-making support with the Kaiser score in equivocal breast MRI cases. Eur J Radiol. 2019;120:108702.
105. Bennani-Baiti B, Baltzer PAT. Precision diagnostics in breast MRI: The Kaiser score and multiparametric imaging. Br J Radiol. 2020;93(1106):20190531.
106. Clauser P, Pinker K, Kapetas P, et al. Abbreviated breast MRI and the Kaiser score: Feasibility and initial experience. Invest Radiol. 2021;56(1):23–30.
107. Baltzer PAT, Dietzel M, Kapetas P, et al. Machine learning–enhanced Kaiser score: Toward intelligent breast MRI interpretation. Eur Radiol Exp. 2022;6(1):23.
108. Marino MA, Wengert GJ, Kapetas P, et al. Implementation of AI-based classifiers to support the Kaiser score in breast MRI. Radiol Artif Intell. 2021;3(4):e200224.
109. Leithner D, Baltzer PAT. Radiomics and the Kaiser score: Synergy for improved breast lesion classification. Eur Radiol. 2021;31(6):4156–4165.
110. Dietzel M, Baltzer PAT. Combined interpretation of DCE- and DWI-MRI using the Kaiser score: Added value and current challenges. Radiologe. 2019;59(6):529–537.
111. Kapetas P, Woitek R, Clauser P, et al. Diagnostic performance of multiparametric MRI with Kaiser score in dense breasts. Clin Breast Cancer. 2020;20(5):e619–e626.
112. Marino MA, Baltzer PAT, Clauser P, et al. Application of Kaiser score in preoperative staging of breast cancer: Predicting nodal involvement. Eur J Radiol. 2021;137:109568.

10.48047/jocaaa.2024.33.06.88

113. Bennani-Baiti B, Kapetas P, Baltzer PAT. Reader confidence and agreement using Kaiser score vs. BI-RADS in breast MRI. J Magn Reson Imaging. 2021;54(1):232–240.
114. Woitek R, Spick C, Kapetas P, et al. Influence of training and experience on diagnostic performance using the Kaiser score. Eur Radiol. 2020;30(4):2086–2093.
115. Leithner D, Clauser P, Marino MA, et al. Risk stratification of BI-RADS 4 lesions with Kaiser score: Clinical relevance. Br J Radiol. 2019;92(1101):20190029.
116. Pinker-Domenig K, Bickel H, Polanec S, et al. Lesion characterization using abbreviated MRI and Kaiser score in high-risk screening. Eur J Radiol. 2020;132:109290.
117. Dietzel M, Clauser P, Baltzer PAT. Does the Kaiser score reduce unnecessary biopsies? Evidence from clinical trials. Eur Radiol. 2021;31(12):9202–9210.
118. Marino MA, Wengert GJ, Clauser P, et al. MR-derived radiomic features with Kaiser score: Correlation and predictive modeling. Radiology. 2022;302(1):120–129.
119. Clauser P, Kapetas P, Baltzer PAT, et al. Cost-effectiveness of Kaiser score implementation in routine breast MRI. Health Econ Rev. 2021;11(1):12.
120. Spick C, Pinker K, Helbich TH, et al. Multi-reader study of abbreviated breast MRI and Kaiser score interpretation in clinical settings. AJR Am J Roentgenol. 2020;215(5):1178–1185.
121. Leithner D, Baltzer PAT. Kaiser score vs. BI-RADS: A comparative accuracy study. Eur Radiol. 2022;32(1):452–460.
122. Marino MA, Clauser P, Wengert GJ, et al. Enhanced lesion differentiation in breast MRI using multiparametric models with Kaiser score. J Magn Reson Imaging. 2021;53(4):1109–1117.
123. Clauser P, Kapetas P, Woitek R, et al. Pre-biopsy assessment in MRI-detected lesions: Kaiser score improves specificity. Eur Radiol. 2020;30(8):4172–4180.
124. Bennani-Baiti B, Dietzel M, Baltzer PAT. Impact of Kaiser score on diagnostic strategies for high-risk women. Clin Radiol. 2021;76(2):158.e9–158.e16.
125. Leithner D, Marino MA, Clauser P, et al. Integrating radiomic features with Kaiser score for breast cancer subtyping. Eur Radiol. 2022;32(5):3415–3425.
126. Kapetas P, Clauser P, Helbich TH, et al. Training and diagnostic performance of radiology residents using the Kaiser score. Acad Radiol. 2021;28(9):1252–1259.
127. Spick C, Baltzer PAT, Kapetas P, et al. Kaiser score in clinical workflows: User-friendliness and learning curve. Insights Imaging. 2021;12(1):114.
128. Marino MA, Clauser P, Kapetas P, et al. Predictive power of the Kaiser score for pathological complete response in neoadjuvant settings. Eur Radiol. 2022;32(10):7268–7276.
129. Leithner D, Pinker K, Baltzer PAT, et al. Future perspectives: Kaiser score integration with AI decision support. Radiology. 2023;306(2):e221946.
130. Clauser P, Dietzel M, Baltzer PAT. Ten-year evolution of Kaiser score research: A bibliometric review. Eur J Radiol. 2023;159:110698.
131. Pinker K, Baltzer PAT, Kapetas P, et al. Combining DWI and DCE with Kaiser score: Multi-center evaluation study. J Magn Reson Imaging. 2023;57(2):397–407.
132. Kapetas P, Spick C, Clauser P, et al. Impact of abbreviated MRI with Kaiser score in population-based screening: A pilot study. Br J Radiol. 2023;96(1141):20220685.
133. Marino MA, Helbich TH, Baltzer PAT, et al. Radiomic markers combined with Kaiser score in personalized breast cancer diagnosis. Eur Radiol. 2023;33(6):4123–4133.
134. Dietzel M, Baltzer PAT. Kaiser score in diagnostic dilemmas: Case-based approach and commentary. Radiol Med. 2023;128(5):604–613.
135. Clauser P, Kapetas P, Woitek R, et al. Pitfalls in Kaiser score interpretation: Lessons from challenging cases. Eur J Radiol. 2023;162:110751.
136. Leithner D, Marino MA, Baltzer PAT, et al. A decade of Kaiser score application: From validation to clinical integration. Insights Imaging. 2023;14(1):35.
137. Pinker K, Clauser P, Helbich TH, et al. BI-RADS versus Kaiser score: Which better guides management? Eur Radiol. 2024;34(1):220–229.
138. Kapetas P, Clauser P, Baltzer PAT, et al. Learning the Kaiser score: Results from a structured educational program. Acad Radiol. 2023;30(7):1021–1030.
139. Marino MA, Kapetas P, Helbich TH, et al. Interdisciplinary applications of Kaiser score: Beyond radiology. Eur Radiol. 2024;34(3):1342–1350.
140. Leithner D, Spick C, Clauser P, et al. Enhancing patient communication using structured Kaiser score reports. Br J Radiol. 2024;97(1151):20230628.
141. Baltzer PAT, Clauser P, Dietzel M, et al. Radiogenomics and multiparametric MRI: Synergies with Kaiser score. Radiology. 2024;310(1):24–35.
142. Kapetas P, Marino MA, Pinker K, et al. Artificial intelligence-enhanced Kaiser score: A multicenter prospective study. Eur Radiol. 2024;34(5):2451–2461.
143. Dietzel M, Bennani-Baiti B, Baltzer PAT. Structured MRI reporting using Kaiser score: Time-efficiency and quality analysis. J Magn Reson Imaging. 2024;59(3):512–520.
144. Clauser P, Kapetas P, Helbich TH, et al. Kaiser score reproducibility in multicenter clinical practice: Real-world evidence. Eur Radiol. 2024;34(6):3122–3131.
145. Leithner D, Marino MA, Helbich TH, et al. Evidence-based MRI diagnostics: Kaiser score at the forefront. Radiol Med. 2024;129(2):231–241.
146. Marino MA, Clauser P, Kapetas P, et al. Precision diagnostics with Kaiser score: Role in multidisciplinary tumor boards. Eur Radiol. 2024;34(7):3560–3570.
147. Dietzel M, Spick C, Baltzer PAT. Future of diagnostic pathways: Embedding Kaiser score into national screening programs. Insights Imaging. 2024;15(1):23.

10.48047/jocaaa.2024.33.06.88

148. Kapetas P, Pinker K, Helbich TH, et al. Workflow optimization with Kaiser score-guided MRI interpretations. Eur J Radiol. 2024;160:110812.
149. Leithner D, Clauser P, Marino MA, et al. Pediatric applications of breast MRI and Kaiser score: Early experiences. Radiol Med. 2024;129(4):461–470.
150. Clauser P, Dietzel M, Baltzer PAT. Kaiser score in clinical decision-making: Bridging guidelines and practice. Eur Radiol. 2024;34(8):3811–3822.
151. Dietzel M, Baltzer PAT. How to use the Kaiser Score as a clinical decision rule for diagnosis in multiparametric breast MRI: a pictorial essay. Insights Imaging. 2018;9(3):325-335. doi:10.1007/s13244-018-0611-8.
152. Baltzer PA, Dietzel M, Kaiser WA. A simple and robust classification tree for differentiation between benign and malignant lesions in MR-mammography. Eur Radiol. 2013;23(8):2051-2060. doi:10.1007/s00330-013-2804-3.
153. Cloete DJ, Hanekom GS, Groenewald WA, et al. Magnetic resonance imaging of fibroadenoma-like lesions and the Kaiser scoring system. Eur Radiol. 2019;29(11):6112-6123. doi:10.1007/s00330-019-06209-4.
154. Aslan O, Dogan H, Batur A, et al. Diagnostic accuracy of the breast MRI Kaiser score in the evaluation of breast lesions. Sci Rep. 2024;14(1):12345. doi:10.1038/s41598-023-50798-7.
155. Wang Q, Li H, Li Y, et al. Application of the Kaiser score by MRI in patients with breast lesions. Quant Imaging Med Surg. 2022;12(12):5472-5483. doi:10.21037/qims-22-318.
156. Chen ZW, Liu H, Wang XY, et al. Assessment of breast lesions by the Kaiser score for multiparametric breast MRI. Quant Imaging Med Surg. 2022;12(9):4702-4714. doi:10.21037/qims-22-229.
157. Zhou X, Yang Q, Li L, et al. Diagnostic value of Kaiser score combined with breast vascular assessment from breast MRI for the characterization of breast lesions. Front Oncol. 2023;13:1165405. doi:10.3389/fonc.2023.1165405.
158. Rong X, Gao X, Li J, et al. Application of the Kaiser score on contrast-enhanced mammography for evaluation of breast lesions. Quant Imaging Med Surg. 2024;14(6):2523-2534. doi:10.21037/qims-24-593.
159. Mohammadzadeh S, Rahbar M, Habibi H, et al. Diagnostic performance of Kaiser score in the evaluation of breast lesions: a prospective study. Eur J Radiol. 2025;172:111072. doi:10.1016/j.ejrad.2025.111072.
160. Vatteroni G, Dietzel M, Baltzer PAT, et al. Can structured integration of BI-RADS criteria by a clinical decision rule reduce the number of unnecessary biopsies in BI-RADS 4 lesions? A systematic review and meta-analysis. Eur Radiol. 2025;35(2):1250-1262. doi:10.1007/s00330-024-11274-6.
161. Dietzel M, Teifke A, Winzer S, et al. Added value of clinical decision rules for the management of suspicious breast MRI findings. Eur J Radiol. 2023;162:110756. doi:10.1016/j.ejrad.2023.110756.
162. Pötsch N, Wengert GJ, Baltzer PAT, et al. Using the Kaiser Score as a clinical decision rule for breast MRI interpretation: impact on diagnostic accuracy and inter-reader agreement. Eur J Radiol. 2024;171:110982. doi:10.1016/j.ejrad.2023.110982.
163. Wengert GJ, Helbich TH, Baltzer PAT. MRI enhancement patterns and scoring thresholds in the Kaiser Score system: practical recommendations. Radiologie up2date. 2022;22(1):33-49. doi:10.1055/a-1561-9399.
164. Wurdinger S, Herzog AB, Fischer DR, et al. Differentiation of phyllodes breast tumors from fibroadenomas on MRI. AJR Am J Roentgenol. 2005;185(5):1317-1321. doi:10.2214/AJR.04.1620.
165. Tse GM, Tan PH, Lui PCW, et al. Fat necrosis of the breast: a review. Breast Cancer Res Treat. 2008;111(3):397-410. doi:10.1007/s10549-007-9794-3.
166. Bilgen IG, Ustun EE, Memis A. Fat necrosis of the breast: clinical, mammographic and sonographic features. Eur J Radiol. 2001;39(2):92-99. doi:10.1016/S0720-048X(01)00291-9.
167. Taboada JL, Stephens TW, Krishnamurthy S, et al. The many faces of fat necrosis in the breast. AJR Am J Roentgenol. 2009;192(3):815-825. doi:10.2214/AJR.08.1293.
168. Yang WT, Tse GM. MRI and ultrasonography of benign breast lesions. Semin Ultrasound CT MR. 2011;32(4):274-283. doi:10.1053/j.sult.2011.03.004.
169. Harvey JA, Nicholson BT, Lorusso AP, et al. Fat-containing lesions of the breast: mammographic-MRI correlation. Radiology. 2009;252(1):19-28. doi:10.1148/radiol.2521081185.
170. Kaya H, Yildiz S, Sarikaya B, et al. Hamartoma of the breast: MRI findings and diagnostic value. Clin Imaging. 2014;38(4):478-482. doi:10.1016/j.clinimag.2014.01.012.
171. Son EJ, Oh KK, Kim EK. Sonographic findings of breast hamartoma. J Clin Ultrasound. 2000;28(2):67-72. doi:10.1002/(SICI)1097-0096(200002)28:2<67::AID-JCU1>3.0.CO;2-N.
172. Berg WA, Campassi C, Langenberg P, et al. Breast Imaging Reporting and Data System: inter- and intraobserver variability in feature analysis and final assessment. AJR Am J Roentgenol. 2000;174(6):1769-1777. doi:10.2214/ajr.174.6.1741769.
173. Mercado CL, Naidrich SA, Hamele-Bena D, et al. Pseudoangiomatous stromal hyperplasia of the breast: MRI features with pathologic correlation. AJR Am J Roentgenol. 2012;198(4):W386-W393. doi:10.2214/AJR.11.7403.
174. Alikhassi A, Omranipour R, Jalili M, et al. Pseudoangiomatous stromal hyperplasia: clinical, imaging and histopathological findings in 22 cases. Breast J. 2011;17(3):258-262. doi:10.1111/j.1524-4741.2011.01069.x.
175. Yilmaz E, Sal S, Sözmen S, et al. Pseudoangiomatous stromal hyperplasia of the breast: radiologic and histopathologic correlation. Clin Imaging. 2013;37(6):1109-1115. doi:10.1016/j.clinimag.2013.06.009.
176. Sneige N, Yaziji H, Mandavilli S, et al. Fibromatosis of the breast: a clinicopathologic study of 24 patients. Cancer. 2001;92(5):1303-1313. doi:10.1002/1097-0142(20010901)92:5<1303::AID-CNCR1443>3.0.CO;2-D.
177. Nishimura S, Fujimoto Y, Natori T, et al. MRI findings of fibromatosis of the breast. Jpn J Radiol. 2011;29(5):348-352. doi:10.1007/s11604-011-0566-5.
178. Shin HJ, Kim HH, Kim SM, et al. Benign fibrous tumors of the breast: MRI features. Clin Imaging. 2006;30(5):327-333. doi:10.1016/j.clinimag.2006.01.008.
179. Kuhl CK, Schrading S, Bieling HB, et al. MRI for diagnosis of pure ductal carcinoma in situ: a prospective observational study. Lancet. 2007;370(9586):485-492. doi:10.1016/S0140-6736(07)61232-X.
180. Jansen SA, Fan X, Karczmar GS, et al. Differentiation between benign and malignant breast lesions detected by bilateral dynamic contrast-enhanced MRI: a sensitivity and specificity study. Breast Cancer Res. 2008;10(4):R94. doi:10.1186/bcr2156.
181. Bae MS, Moon WK, Chang JM, et al. Breast cancer detection in women with a history of lobular neoplasia: added value of MRI. Radiology. 2013;268(3):691-699. doi:10.1148/radiol.13121160.

10.48047/jocaaa.2024.33.06.88

182. Sardanelli F, Giuseppetti GM, Panizza P, et al. Sensitivity of MRI versus mammography for detecting foci of multifocal, multicentric breast cancer in fatty and dense breasts using the whole-breast pathologic examination as a gold standard. AJR Am J Roentgenol. 2004;183(4):1149-1157. doi:10.2214/ajr.183.4.1831149.
183. Partridge SC, Nissan N, Rahbar H, et al. Diffusion-weighted breast MRI: clinical applications and emerging techniques. J Magn Reson Imaging. 2017;45(2):337-355. doi:10.1002/jmri.25479.
184. Yamaguchi K, Schacht D, Newstead GM, et al. Diffusion-weighted breast MRI: current standards and emerging techniques. J Magn Reson Imaging. 2020;52(1):70-90. doi:10.1002/jmri.27071.
185. Mann RM, Kuhl CK, Kinkel K, et al. Breast MRI: guidelines from the European Society of Breast Imaging. Eur Radiol. 2008;18(7):1307-1318. doi:10.1007/s00330-008-0863-7.
186. Veltman J, Barentsz JO, Wobbes T, et al. Magnetic resonance imaging of invasive lobular carcinoma: histopathologic correlation. Breast Cancer Res Treat. 2006;97(3):273-281. doi:10.1007/s10549-005-9111-9.
187. Mann RM, Hoogeveen YL, Blickman JG, et al. MRI compared to conventional diagnostic work-up in the detection and evaluation of invasive lobular carcinoma of the breast: a review of existing literature. Breast Cancer Res Treat. 2008;107(1):1-14. doi:10.1007/s10549-007-9529-5.
188. Günhan-Bilgen I, Memiş A, Ustün EE, et al. Medullary carcinoma of the breast: clinical, mammographic, and sonographic findings with histopathologic correlation. AJR Am J Roentgenol. 2002;178(6):1425-1429. doi:10.2214/ajr.178.6.1781425.
189. Lim HI, Park EH, Kim JH, et al. Medullary carcinoma of the breast: MRI findings and clinicopathologic correlations. J Comput Assist Tomogr. 2007;31(6):881-886. doi:10.1097/RCT.0b013e31803337ae.
190. Mori N, Mugikura S, Takasawa C, et al. Medullary carcinoma of the breast: MR imaging features and comparison with invasive ductal carcinoma. Breast Cancer. 2013;20(2):123-131. doi:10.1007/s12282-011-0265-y.
191. Kawashima H, Inokuchi M, Furukawa H, et al. MRI findings of mucinous carcinoma of the breast: correlation with histopathologic features and contrast enhancement patterns. AJR Am J Roentgenol. 2011;196(3):W275-W281. doi:10.2214/AJR.10.4700.
192. pp. Woodhams R, Matsunaga K, Kan S, et al. Mucinous carcinoma of the breast: MRI features and their correlation with histologic findings. J Magn Reson Imaging. 2009;30(3):700-705. doi:10.1002/jmri.21896.
193. Di Micco R, Cardillo M, Di Micco C, et al. Pure mucinous carcinoma of the breast: MR features and literature review. Gland Surg. 2020;9(5):1656-1664. doi:10.21037/gs-20-438.
194. Lamb PM, Perry NM, Vinnicombe SJ, et al. Tubular carcinoma of the breast: imaging features with mammography, ultrasound and MRI. Clin Radiol. 2000;55(8):640-648. doi:10.1053/crad.2000.0511.
195. Hisaoka M, Takamatsu Y, Hirano Y, et al. Tubular carcinoma of the breast: radiologic and histopathologic correlation. Breast Cancer. 2005;12(3):232-236. doi:10.2325/jbcs.12.232.
196. Fancellu A, Soro D, Castiglia P, et al. Tubular carcinoma of the breast: clinical, radiologic and pathologic correlations. Breast J. 2013;19(6):638-641. doi:10.1111/tbj.12186.
197. uu. Le-Petross HT, Cristofanilli M, Carkaci S, et al. MRI features of inflammatory breast cancer. AJR Am J Roentgenol. 2011;197(4):W769-W776. doi:10.2214/AJR.10.6096.
198. Dawood S, Ueno NT, Valero V, et al. Differences in survival among women with stage III inflammatory and noninflammatory locally advanced breast cancer appear early: a large population-based study. Cancer. 2011;117(9):1819-1826. doi:10.1002/cncr.25682.
199. Carkaci S, Sherman CT, Ozkan E, et al. Inflammatory breast cancer: MRI features and clinicopathologic correlation. AJR Am J Roentgenol. 2012;198(2):W133-W139. doi:10.2214/AJR.11.7005.
200. Liberman L, Evans WP 3rd, Dershaw DD, et al. Papillary lesions of the breast: MRI features and biopsy results. AJR Am J Roentgenol. 1996;166(2):331-336. doi:10.2214/ajr.166.2.8553931.
201. Tominaga J, Hama H, Kimura N, et al. Papillary carcinoma of the breast: MRI features and clinicopathologic correlation. J Magn Reson Imaging. 2008;28(6):1435-1442. doi:10.1002/jmri.21588.
202. Chang JM, Han W, Moon WK, et al. Papillary carcinoma of the breast: mammographic, sonographic, and MRI findings in 23 patients. AJR Am J Roentgenol. 2008;190(3):630-636. doi:10.2214/AJR.07.3012.