Diagnostic Performance of the Kaiser Score for Characterization of Breast Lesions on Unenhanced Breast MRI: A Comprehensive Review

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Abstract

Background: Breast magnetic resonance imaging (MRI) is recognized as the most sensitive imaging modality for the detection and characterization of breast cancer. Conventional breast MRI relies heavily on dynamic contrast-enhanced MRI (DCE-MRI), which provides both morphological and kinetic information for lesion assessment. However, concerns regarding gadolinium-based contrast agent administration, increased examination time, higher costs, and limited accessibility have stimulated interest in unenhanced breast MRI protocols. Diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) measurements have emerged as promising alternatives, offering functional information without the need for contrast administration. While lesion detection using unenhanced MRI has shown encouraging results, accurate lesion characterization remains challenging due to the absence of standardized decision-support tools. This review aims to evaluate the diagnostic performance of the Kaiser Score (KS) for characterization of breast lesions on unenhanced breast MRI and to discuss its potential role as a structured clinical decision-making tool for differentiating benign from malignant breast lesions. The review further explores modifications of the conventional KS that incorporate DWI and ADC parameters to overcome the limitations associated with the absence of contrast-enhanced kinetic information.

The Kaiser Score is a validated MRI-based clinical decision rule originally developed for contrast-enhanced breast MRI using five BI-RADS-derived imaging features. Its structured approach has demonstrated high diagnostic accuracy, improved specificity, and reduced unnecessary biopsies compared with conventional BI-RADS assessment. Recent studies have investigated the adaptation of the Kaiser Score to unenhanced breast MRI by replacing enhancement curve analysis with diffusion-related parameters, particularly ADC values. Evidence suggests that combining lesion morphology on T2-weighted imaging and DWI with quantitative ADC assessment may preserve the diagnostic strengths of the original KS while eliminating the need for contrast administration. Emerging data indicate that modified unenhanced Kaiser Score models achieve promising sensitivity, specificity, and overall diagnostic accuracy, approaching those reported for conventional multiparametric MRI.

Conclusion: The Kaiser Score represents a promising strategy for standardized lesion characterization in unenhanced breast MRI. Integration of DWI and ADC-based criteria into the Kaiser framework may facilitate accurate differentiation between benign and malignant breast lesions while supporting the development of faster, safer, and more cost-effective breast MRI protocols. Although current evidence is encouraging, further multicenter prospective studies and standardization of unenhanced imaging protocols are required before widespread clinical implementation can be recommended.

Keywords: *Kaiser Score , Breast Lesions ,Unenhanced Breast MRI:*

Introduction

Breast cancer remains the most frequently diagnosed malignancy among women worldwide and represents a leading cause of cancer-related mortality despite continuous advances in screening, diagnosis, and treatment. Early detection and accurate characterization of breast lesions are essential for improving patient outcomes, guiding therapeutic decisions, and reducing unnecessary invasive procedures. Although the majority of breast lesions encountered in clinical practice are benign, differentiating benign from malignant lesions remains a major diagnostic challenge, particularly in women with dense breast tissue and inconclusive findings on conventional imaging modalities. Consequently, imaging techniques with high sensitivity and specificity are crucial for optimizing breast cancer diagnosis and management. [1,2]

Breast magnetic resonance imaging (MRI) has become an indispensable component of contemporary breast imaging owing to its superior soft-tissue contrast and exceptional sensitivity for cancer detection. Compared with mammography and ultrasound, breast MRI offers enhanced lesion visualization and improved assessment of tumor extent, multifocality, multicentricity, and contralateral disease. Furthermore, MRI has demonstrated significant value in screening high-risk women, evaluating treatment response, and solving diagnostic dilemmas encountered during routine breast imaging. These advantages have established breast MRI as the most sensitive imaging modality for breast cancer detection and characterization. [3,4]

Traditionally, breast MRI protocols have relied on dynamic contrast-enhanced MRI (DCE-MRI), which evaluates lesion morphology together with enhancement kinetics following intravenous administration of gadolinium-based contrast agents. The diagnostic performance of DCE-MRI is largely attributable to its ability to depict tumor neoangiogenesis and vascular permeability, characteristics commonly associated with malignant lesions. Assessment of enhancement patterns and time–signal intensity curves has therefore become a cornerstone of MRI-based lesion characterization and is incorporated into the Breast Imaging Reporting and Data System (BI-RADS) MRI lexicon. Nevertheless, DCE-MRI is associated with several limitations, including increased examination time, higher cost, restricted accessibility, and concerns regarding gadolinium deposition and contrast administration in selected patient populations. [5,6]

Growing awareness of these limitations has stimulated substantial interest in the development of unenhanced breast MRI protocols. In recent years, diffusion-weighted imaging (DWI) has emerged as the most promising non-contrast MRI technique for breast lesion assessment. DWI provides functional information by evaluating the random movement of water molecules within tissues and enables quantitative measurement through apparent diffusion coefficient (ADC) values. Malignant breast tumors typically exhibit restricted diffusion due to increased cellularity and reduced extracellular space, resulting in lower ADC values compared with benign lesions. Consequently, DWI has shown considerable potential for both lesion detection and lesion characterization without the need for contrast administration. [7–9]

Several investigations have demonstrated that unenhanced MRI protocols combining DWI, ADC mapping, and conventional T2-weighted sequences can achieve diagnostic performances approaching those of contrast-enhanced examinations. Moreover, abbreviated and unenhanced MRI protocols offer important practical advantages, including shorter acquisition times, reduced examination costs, improved patient tolerance, and elimination of risks related to gadolinium administration. These benefits have increased interest in incorporating unenhanced MRI into breast cancer screening programs and routine clinical practice, particularly for patients with contraindications to contrast agents and in resource-limited healthcare settings. [7,10,11]

Despite these advances, lesion characterization remains the principal limitation of unenhanced breast MRI. While DWI facilitates lesion detection and provides valuable biological information, interpretation of diffusion findings alone may be challenging due to overlap in ADC values between certain benign and malignant lesions. Furthermore, the absence of enhancement kinetics eliminates one of the most powerful diagnostic features traditionally used in breast MRI interpretation. Therefore, there remains a need for standardized and reproducible decision-support tools capable of maintaining high diagnostic accuracy within a contrast-free imaging environment. [8,12]

To address variability in breast MRI interpretation, Baltzer and colleagues developed the Kaiser Score (KS), a structured clinical decision rule based on five BI-RADS-derived imaging criteria. Unlike conventional subjective interpretation, the KS uses a diagnostic flowchart that integrates lesion margins, enhancement characteristics, kinetic behavior, and other morphological features to generate a numerical score reflecting the probability of malignancy. Multiple studies have demonstrated that the KS improves diagnostic accuracy, increases specificity, reduces unnecessary biopsies, and enhances interobserver agreement among radiologists with varying levels of experience. Consequently, the Kaiser Score has become one of the most extensively validated decision-support systems in breast MRI. [13,14]

However, the original Kaiser Score was specifically designed for contrast-enhanced MRI and depends substantially on kinetic curve assessment, which represents one of the most influential components of the scoring algorithm. This dependence limits its direct application to unenhanced MRI protocols. Recent research has therefore focused on adapting the KS for contrast-free breast imaging by replacing kinetic curve analysis with diffusion-related parameters, particularly ADC measurements derived from DWI. Emerging evidence suggests that integrating ADC values into modified KS algorithms may preserve the diagnostic strengths of the original model while enabling accurate lesion characterization without contrast administration. [15–17]

The increasing adoption of unenhanced breast MRI, combined with the growing body of evidence supporting DWI-based lesion assessment, has created a need to critically evaluate the role of the Kaiser Score in this evolving imaging paradigm. Although several recent studies have investigated modified KS models and their diagnostic performance, the available evidence remains fragmented and requires comprehensive synthesis. Furthermore, uncertainty persists regarding the reliability, clinical applicability, and future integration of unenhanced KS approaches into routine breast imaging workflows. [15–18]

Therefore, this review aims to comprehensively evaluate the diagnostic performance of the Kaiser Score for characterization of breast lesions on unenhanced breast MRI. Particular emphasis is placed on the adaptation of the conventional KS to diffusion-based imaging protocols, its ability to differentiate benign from malignant breast lesions, comparison with established MRI assessment methods, and its potential role in the development of standardized contrast-free breast MRI pathways.

2. Principles of Breast MRI for Lesion Characterization

Breast magnetic resonance imaging (MRI) has evolved into the most sensitive imaging modality for the detection and characterization of breast cancer. Unlike mammography and ultrasound, MRI provides high-contrast, multiplanar visualization of breast tissue while simultaneously offering both anatomical and functional information. The ability of MRI to assess lesion morphology, vascularity, cellularity, and tissue microenvironment has significantly improved diagnostic confidence in differentiating benign from malignant lesions. Consequently, breast MRI has become an essential component of screening high-risk women, preoperative staging, treatment monitoring, and evaluation of equivocal findings detected by conventional imaging techniques. [19,20]

The diagnostic accuracy of breast MRI depends on a multiparametric approach that integrates morphological assessment with functional imaging techniques. Traditionally, this approach includes T1-weighted imaging, T2-weighted imaging, diffusion-weighted imaging (DWI), apparent diffusion coefficient (ADC) analysis, and dynamic contrast-enhanced MRI (DCE-MRI). The combination of these sequences allows comprehensive evaluation of lesion architecture, internal composition, vascular characteristics, and cellular density. Interpretation is standardized using descriptors defined in the MRI BI-RADS lexicon, which facilitates communication among radiologists and clinicians while promoting consistent lesion assessment. [21,22]

2.1 T1-Weighted Imaging

T1-weighted imaging serves as an important component of breast MRI protocols and is typically acquired before contrast administration. These sequences provide excellent anatomical overview of both breasts and allow assessment of lesion signal characteristics relative to surrounding fibroglandular tissue and fat. Fat-containing lesions such as lipomas and hamartomas often demonstrate high signal intensity on non-fat-suppressed T1-weighted images, facilitating their recognition as benign entities. Additionally, precontrast T1-weighted imaging establishes a baseline for subsequent evaluation of lesion enhancement and generation of subtraction images during contrast-enhanced examinations. Although T1-weighted imaging alone has limited ability to distinguish benign from malignant lesions, it contributes valuable structural information within the multiparametric MRI examination. [23,24]

2.2 T2-Weighted Imaging

T2-weighted imaging provides complementary information regarding tissue composition and lesion internal architecture. Lesions demonstrating marked hyperintensity on T2-weighted images are frequently benign and include cysts, myxoid fibroadenomas, apocrine lesions, and intramammary lymph nodes. Conversely, many invasive breast cancers exhibit relatively low or intermediate T2 signal intensity due to increased cellularity and reduced free water content. However, important exceptions exist, including mucinous carcinoma, necrotic tumors, and some metaplastic carcinomas, which may demonstrate high T2 signal intensity despite malignant histology. Therefore, T2-weighted imaging should always be interpreted alongside morphological and diffusion findings rather than in isolation. [25,26]

In addition to lesion characterization, T2-weighted imaging allows identification of associated findings such as peritumoral edema, skin thickening, and chest wall involvement. Peritumoral edema has been associated with more aggressive tumor biology and poorer prognostic features. Furthermore, assessment of T2 signal intensity plays an important role in modern Kaiser Score algorithms, particularly in modified versions designed for unenhanced MRI protocols where conventional enhancement kinetics are unavailable. [25,27]

2.3 Diffusion-Weighted Imaging

Diffusion-weighted imaging has emerged as the cornerstone of unenhanced breast MRI. DWI evaluates the microscopic motion of water molecules within tissues and provides indirect information regarding tissue cellularity and membrane integrity. Malignant tumors generally demonstrate restricted water diffusion because of increased cell density, enlarged nuclei, and reduced extracellular space. This restriction appears as high signal intensity on high b-value DWI images and corresponding low signal intensity on ADC maps. [7,28]

The major advantage of DWI is that it does not require administration of contrast material while still providing functional information relevant to tumor characterization. This characteristic has generated considerable interest in using DWI as a standalone or complementary technique for breast cancer detection and diagnosis. Numerous studies have demonstrated that DWI significantly improves specificity when combined with conventional MRI and may reduce unnecessary biopsies of benign lesions. Moreover, DWI acquisition requires only a few minutes, making it particularly attractive for abbreviated and screening MRI protocols. [7,12,29]

Technical optimization is essential for obtaining reliable DWI examinations. Factors such as b-values, fat suppression quality, signal-to-noise ratio, and artifact reduction significantly influence image quality and quantitative measurements. Current recommendations generally support the use of b-values between 0 and 800–1000 s/mm^2, providing an optimal balance between lesion conspicuity and image quality. Advances such as readout-segmented echo-planar imaging and reduced field-of-view techniques have further improved spatial resolution and reduced susceptibility artifacts, enhancing lesion visualization and morphological assessment on DWI. [7,30]

2.4 Apparent Diffusion Coefficient (ADC)

The apparent diffusion coefficient is a quantitative parameter derived from DWI that reflects the degree of water diffusion within tissues. ADC values provide objective measurements that assist in differentiating benign from malignant lesions. In general, malignant breast lesions exhibit lower ADC values because of restricted diffusion, whereas benign lesions demonstrate higher ADC values due to relatively unrestricted water movement. This quantitative capability has made ADC one of the most valuable biomarkers in breast MRI. [28,31]

Although considerable overlap exists between certain benign and malignant lesions, multiple studies have shown that ADC measurements improve diagnostic specificity and complement conventional morphological assessment. ADC values have also demonstrated potential utility in predicting tumor grade, molecular subtype, treatment response, and prognostic biomarkers. Importantly, ADC has become a key element in modified Kaiser Score models, where diffusion metrics are used to substitute for enhancement kinetics and preserve diagnostic accuracy within unenhanced MRI protocols. [15,32]

2.5 Dynamic Contrast-Enhanced MRI

Dynamic contrast-enhanced MRI remains the reference standard for breast MRI lesion characterization. Following intravenous administration of gadolinium-based contrast material, sequential T1-weighted acquisitions are obtained to evaluate lesion enhancement patterns over time. DCE-MRI assesses both morphological features and vascular characteristics related to tumor angiogenesis, capillary permeability, and extracellular contrast accumulation. These biological processes often differ substantially between benign and malignant lesions, contributing to the high sensitivity of breast MRI. [5,33]

Interpretation of DCE-MRI incorporates both lesion morphology and enhancement kinetics. Malignant lesions frequently demonstrate rapid initial enhancement followed by plateau or washout kinetics, whereas benign lesions typically exhibit persistent enhancement patterns. Approximately 80–90% of invasive breast cancers show plateau or washout curves, making kinetic assessment a powerful diagnostic tool. These enhancement characteristics constitute a fundamental component of BI-RADS interpretation and form one of the key decision nodes within the original Kaiser Score algorithm. [6,34]

Despite its excellent diagnostic performance, DCE-MRI has several limitations. Contrast administration increases examination complexity, cost, and duration while introducing concerns related to gadolinium deposition and contraindications in selected patient populations. Consequently, increasing efforts have focused on identifying contrast-free alternatives capable of preserving diagnostic accuracy while improving accessibility and patient safety. This transition has provided the foundation for the development of modified Kaiser Score approaches adapted specifically for unenhanced breast MRI. [10,11]

2.6 Multiparametric MRI and the Transition Toward Unenhanced Imaging

Multiparametric MRI combines morphological assessment from T1- and T2-weighted sequences with functional information obtained from DWI and DCE-MRI. This integrated approach provides the highest diagnostic performance currently achievable in breast imaging and serves as the basis for most contemporary MRI interpretation strategies. However, recent evidence suggests that carefully designed unenhanced protocols incorporating high-quality DWI, ADC analysis, and T2-weighted imaging may approach the diagnostic performance of conventional contrast-enhanced examinations. [8,11]

The success of unenhanced MRI depends not only on image acquisition but also on the availability of structured decision-support systems capable of integrating diffusion and morphological findings into reproducible diagnostic pathways. The Kaiser Score represents one of the most promising tools for achieving this objective, and understanding its development and diagnostic principles is essential before evaluating its application within unenhanced breast MRI protocols. [13–15]

3. The Kaiser Score: Concept, Development, and Diagnostic Principles

The interpretation of breast MRI has traditionally relied on the subjective assessment of lesion morphology and enhancement characteristics according to BI-RADS criteria. Although the BI-RADS lexicon provides a standardized framework for reporting breast MRI findings, substantial interobserver variability persists, particularly among less experienced radiologists. This variability may lead to unnecessary biopsies of benign lesions or delayed diagnosis of malignancy. To address these limitations, efforts have been directed toward developing structured diagnostic models capable of translating MRI findings into reproducible and evidence-based clinical decisions. Among these models, the Kaiser Score

(KS) has emerged as one of the most extensively validated and clinically useful decision-support tools for breast lesion characterization. [13,14]

The Kaiser Score was originally developed by Baltzer and colleagues as a clinical decision rule designed to simplify breast MRI interpretation while maintaining high diagnostic accuracy. Unlike conventional scoring systems that assign numerical values to individual imaging findings, the KS employs a decision-tree structure that sequentially analyzes specific MRI features according to their relative diagnostic importance. This approach mimics expert radiological reasoning and guides the interpreter through a structured pathway that ultimately generates a numerical score ranging from 1 to 11, corresponding to increasing probabilities of malignancy. The resulting score can then be translated directly into BI-RADS assessment categories, thereby facilitating clinical management decisions. [13,35]

A major strength of the Kaiser Score is its reliance on a limited number of MRI features that are routinely evaluated during breast MRI interpretation. The original algorithm incorporates five BI-RADS-derived criteria: the presence of spiculated margins, enhancement kinetics represented by the time–signal intensity curve type, lesion margins, internal enhancement pattern, and the presence of ipsilateral edema. These features are assessed sequentially within a decision tree, allowing the radiologist to arrive at a final diagnostic score through a logical and reproducible process. By emphasizing the most diagnostically powerful imaging characteristics, the KS reduces subjective variability and improves consistency among readers. [13,14]

Among the individual variables included in the Kaiser Score, lesion margins represent one of the most influential determinants of malignancy risk. Spiculated margins are strongly associated with invasive breast cancer and therefore occupy a prominent position within the decision tree. Similarly, kinetic assessment derived from DCE-MRI contributes substantially to lesion classification because malignant tumors frequently exhibit plateau or washout enhancement patterns resulting from abnormal tumor angiogenesis and vascular permeability. Internal enhancement characteristics and associated edema provide additional diagnostic information regarding tumor aggressiveness and biological behavior. The integration of these features enables the KS to achieve diagnostic performance superior to that of isolated MRI descriptors. [13,34]

Numerous validation studies have demonstrated the effectiveness of the Kaiser Score in differentiating benign from malignant breast lesions. Across multiple patient populations, the KS has consistently achieved high sensitivity while significantly improving specificity compared with conventional BI-RADS assessment alone. Importantly, the structured nature of the scoring system has been shown to reduce unnecessary biopsies without compromising cancer detection. These findings are particularly relevant in breast MRI, where the high sensitivity of the modality may otherwise be accompanied by relatively low specificity and increased rates of benign tissue sampling. [14,15]

Another important advantage of the Kaiser Score is its ability to improve interobserver agreement. Several investigations have demonstrated that radiologists with varying levels of breast imaging experience can achieve comparable diagnostic performance when applying the KS. This reproducibility is attributable to the algorithm's structured decision pathway, which minimizes reliance on subjective interpretation and reduces ambiguity in lesion assessment. Consequently, the KS has gained acceptance as a valuable educational and clinical tool capable of supporting both experienced breast radiologists and less specialized readers. [14,15]

The increasing popularity of abbreviated breast MRI protocols has further highlighted the value of structured diagnostic algorithms such as the Kaiser Score. Abbreviated MRI examinations aim to reduce acquisition and interpretation times while preserving diagnostic accuracy. However, streamlined protocols may provide less information than comprehensive multiparametric MRI studies, increasing the need for efficient decision-support systems. The KS addresses this challenge by integrating key imaging findings into a practical workflow that facilitates rapid and reliable lesion classification. [11,14]

Despite its proven clinical utility, the original Kaiser Score was developed specifically for contrast-enhanced breast MRI and therefore depends heavily on kinetic information derived from dynamic contrast-enhanced imaging. Enhancement curve analysis represents one of the most influential decision nodes within the algorithm and contributes substantially to its diagnostic accuracy. Consequently, direct application of the original KS to unenhanced MRI protocols is not feasible because kinetic data are unavailable in the absence of gadolinium administration. This limitation has become increasingly relevant as interest grows in contrast-free breast MRI strategies based primarily on diffusion-weighted imaging and ADC analysis. [14–16]

Recent investigations have therefore focused on adapting the Kaiser Score to unenhanced breast MRI environments. These modified approaches seek to replace enhancement kinetics with diffusion-derived biomarkers while preserving the fundamental structure and diagnostic philosophy of the original model. ADC measurements have attracted particular interest because they provide objective quantitative information regarding tissue cellularity and have repeatedly demonstrated diagnostic value in differentiating benign from malignant lesions. Preliminary studies suggest that incorporating ADC thresholds into modified KS algorithms may achieve diagnostic performances approaching those of conventional contrast-enhanced MRI. [15–17]

The successful adaptation of the Kaiser Score to unenhanced breast MRI would represent an important advance in breast imaging by combining the strengths of structured clinical decision-making with the practical advantages of contrast-free MRI protocols. Understanding the principles, strengths, and limitations of the original Kaiser Score is therefore essential before evaluating the emerging evidence regarding its application in unenhanced breast MRI and its potential role in future breast imaging pathways. [14–17]

4. Diagnostic Performance of the Conventional Kaiser Score

The conventional Kaiser Score has been developed as a structured MRI-based decision rule to improve differentiation between benign and malignant breast lesions. Its diagnostic value arises from combining the most relevant BI-RADS-derived MRI descriptors within a practical decision-tree model. Rather than relying on isolated imaging signs, the score integrates lesion morphology, margin characteristics, enhancement pattern, kinetic behavior, and associated edema into a single probability-based assessment. This structured approach is particularly valuable because breast MRI is highly sensitive but may suffer from variable specificity when interpreted subjectively. Therefore, the Kaiser Score aims to preserve the high cancer detection capability of breast MRI while reducing false-positive interpretations and unnecessary biopsies. [13–15]

Several studies have shown that the Kaiser Score provides high diagnostic accuracy for breast lesion characterization, with excellent sensitivity and improved specificity compared with conventional BI-RADS-based interpretation alone. The major clinical advantage of the score is its ability to downgrade probably benign or low-suspicion lesions when the imaging features do not support malignancy, while maintaining appropriate suspicion for lesions with high-risk morphological and kinetic features. This is especially important in MRI-detected lesions, where biopsy rates may be increased because of the high sensitivity of contrast-enhanced MRI and the overlap between benign proliferative lesions and malignant tumors. [14,15]

Compared with routine visual MRI interpretation, the Kaiser Score improves reproducibility by reducing dependence on individual reader experience. In conventional breast MRI practice, interpretation may differ between expert breast radiologists and general radiologists, particularly when assessing non-classic lesions or BI-RADS 4 findings. The Kaiser Score provides a defined pathway that helps standardize the diagnostic process and supports more consistent assignment of malignancy probability. This advantage is clinically relevant because improved interobserver agreement can lead to more uniform patient management, fewer unnecessary biopsies, and better communication between radiologists, surgeons, and oncologists. [13,14]

The diagnostic performance of the Kaiser Score is strongly related to the weighting of its internal decision nodes. Spiculated margins and suspicious lesion borders are among the strongest predictors of malignancy and usually drive the score toward a higher-risk category. Enhancement kinetics also play a central role, as plateau and washout curves are more frequently associated with malignant lesions, whereas persistent enhancement is more commonly observed in benign lesions. Internal enhancement characteristics and ipsilateral edema provide additional biological information, reflecting tumor heterogeneity, angiogenesis, and surrounding tissue reaction. The integration of these findings explains why the Kaiser Score generally performs better than single-feature assessment. [6,13,34]

One of the most important applications of the Kaiser Score is the evaluation of BI-RADS 4 lesions. BI-RADS 4 is a broad category that includes lesions with a wide range of malignancy probabilities, and many lesions assigned to this category ultimately prove benign after biopsy. By applying the Kaiser Score, radiologists may better stratify these indeterminate lesions into lower- and higher-risk groups. Studies evaluating MRI BI-RADS 4 lesions have shown that structured assessment and additional functional parameters such as DWI and ADC can help identify lesions suitable for downgrading, potentially avoiding unnecessary biopsy while maintaining diagnostic safety. [12,14,15]

The performance of the Kaiser Score is also enhanced by its compatibility with multiparametric MRI interpretation. Although the original score is based on contrast-enhanced MRI features, it does not ignore morphology; rather, it gives morphology a central role in the diagnostic pathway. This is important because malignant breast lesions often demonstrate irregular shape, non-circumscribed margins, rim enhancement, and associated edema, while many benign lesions show oval or round shape, circumscribed margins, homogeneous internal pattern, or benign T2 features. Therefore, the Kaiser Score reflects the way expert breast radiologists synthesize multiple imaging signs rather than relying on enhancement kinetics alone. [13,21,26]

Despite its favorable performance, the conventional Kaiser Score has important limitations. Its strongest limitation in the context of this review is its dependence on dynamic contrast-enhanced MRI, particularly enhancement curve type. Because kinetic behavior is unavailable in unenhanced MRI, the original score cannot be directly transferred to contrast-free protocols without modification. In addition, some malignant lesions, such as mucinous carcinoma or certain low-grade cancers, may show benign-appearing morphology or high T2 signal, while some benign inflammatory or proliferative lesions may show suspicious enhancement. These overlapping features underline the need for careful interpretation and support the development of modified Kaiser approaches incorporating diffusion and ADC parameters. [15–17,25]

The conventional Kaiser Score represents a validated and clinically useful decision-support tool for breast MRI interpretation. Its major strengths include high sensitivity, improved specificity, better reproducibility, and potential reduction of unnecessary biopsies compared with subjective assessment alone. However, the increasing interest in abbreviated and unenhanced breast MRI has created a new diagnostic challenge: how to preserve the structured accuracy of the Kaiser Score when contrast enhancement and kinetic curve analysis are not available. This challenge forms the rationale for adapting the Kaiser Score to unenhanced breast MRI using DWI, ADC mapping, and T2-weighted morphological assessment. [17]

5. Unenhanced Breast MRI: Rationale, Technique, and Diagnostic Value

Unenhanced breast MRI has gained increasing attention as a potential alternative to conventional dynamic contrast-enhanced MRI, particularly in clinical scenarios where gadolinium administration is undesirable, contraindicated, costly, or unavailable. The main concept of unenhanced MRI is to preserve the high soft-tissue contrast and functional information of MRI while avoiding contrast injection. This approach is especially relevant for screening programs, follow-up examinations, patients with renal impairment, pregnant or lactating women in selected situations, and patients requiring repeated MRI examinations. In breast imaging, the growing interest in contrast-free protocols is also driven by the need to reduce examination time, improve patient tolerance, and increase accessibility without substantially compromising diagnostic accuracy. [7,10,11]

The technical foundation of unenhanced breast MRI is based mainly on diffusion-weighted imaging, apparent diffusion coefficient mapping, and T2-weighted imaging. DWI provides functional information related to tissue cellularity, while ADC offers quantitative measurement of water diffusion. Malignant breast lesions usually demonstrate high signal intensity on high b-value DWI and low ADC values because of restricted diffusion caused by dense tumor cellularity and reduced extracellular space.

In contrast, many benign lesions show higher ADC values due to less restricted water motion. Therefore, DWI and ADC are central components of unenhanced breast MRI protocols and represent the main substitute for contrast-enhanced functional assessment. [7,8,28]

T2-weighted imaging provides additional morphological and tissue-composition information in unenhanced protocols. Cysts, fibroadenomas with myxoid components, inflammatory lesions, fat necrosis, and intramammary lymph nodes may demonstrate characteristic T2 features that support benign diagnosis. Conversely, many malignant tumors show low or intermediate T2 signal intensity, irregular morphology, and surrounding edema. However, interpretation must remain cautious because some cancers, including mucinous carcinoma, necrotic carcinoma, and metaplastic carcinoma, may demonstrate high T2 signal intensity. Thus, T2-weighted imaging improves diagnostic confidence but should not be used as an isolated discriminator. [25–27]

The diagnostic value of unenhanced breast MRI has been supported by studies showing that DWI-based protocols can detect and characterize breast cancers with promising accuracy. Unenhanced MRI may depict lesions as high signal abnormalities on DWI in a manner that resembles lesion conspicuity on contrast-enhanced subtraction images. This ability is particularly useful because DWI acquisition is rapid, does not require intravenous access, and can be incorporated easily into abbreviated MRI protocols. Studies evaluating unenhanced MRI have suggested that DWI combined with T2-weighted imaging may achieve acceptable sensitivity and specificity for differentiating benign from malignant breast lesions, although performance varies according to lesion type, size, imaging technique, and ADC threshold selection. [10,11,16]

A major advantage of unenhanced breast MRI is its potential to improve specificity when ADC analysis is integrated into lesion assessment. Many benign enhancing lesions that appear suspicious on DCE-MRI may demonstrate relatively high ADC values, allowing radiologists to downgrade them and reduce unnecessary biopsy. Conversely, lesions with restricted diffusion and low ADC values require careful evaluation even when morphology appears relatively circumscribed, because some aggressive tumors, including triple-negative cancers, may present with deceptively benign margins. This interaction between morphology and diffusion behavior is one of the reasons why a structured model such as the modified Kaiser Score may be superior to ADC-only interpretation. [12,15,17]

Despite these advantages, unenhanced breast MRI has important limitations. DWI is susceptible to artifacts, distortion, low spatial resolution, and variability related to scanner field strength, coil type, fat suppression, b-value selection, and acquisition technique. ADC measurements may vary across institutions and may overlap between benign and malignant lesions. Small lesions, non-mass lesions, ductal carcinoma in situ, and lesions located near the chest wall or nipple may be more difficult to assess using DWI alone. These limitations explain why unenhanced MRI has not fully replaced contrast-enhanced MRI and why standardization remains essential before broad clinical implementation. [7,8,30]

The absence of enhancement kinetics is the most important interpretive challenge in unenhanced MRI. In conventional breast MRI, time–signal intensity curves provide valuable information regarding tumor vascularity and permeability. Without contrast administration, radiologists lose access to early enhancement, washout, plateau, and persistent curve patterns. Therefore, unenhanced MRI requires alternative diagnostic criteria that can compensate for the missing kinetic information. ADC values, DWI signal intensity, lesion margins, T2 signal, and edema assessment become increasingly important in this setting. [6,15,16]

In this context, unenhanced breast MRI should not be viewed merely as a shortened version of conventional MRI, but rather as a distinct diagnostic strategy requiring its own structured interpretation pathway. The Kaiser Score provides a strong conceptual basis for such a pathway because it already combines morphology and functional imaging features in a reproducible decision-tree format. Modifying the Kaiser Score for unenhanced MRI by replacing contrast kinetic information with ADC-based diffusion assessment may allow radiologists to retain standardized lesion characterization while avoiding gadolinium administration. This represents the central rationale for evaluating the diagnostic performance of the Kaiser Score in unenhanced breast MRI. [15–17]

6. Adaptation of the Kaiser Score for Unenhanced Breast MRI

The growing interest in unenhanced breast MRI has created a significant challenge for breast imaging specialists: how to maintain the diagnostic performance of established MRI interpretation models without relying on contrast enhancement. Among the available diagnostic tools, the Kaiser Score has demonstrated excellent performance in contrast-enhanced breast MRI; however, its dependence on enhancement kinetics limits its direct application in contrast-free examinations. Consequently, recent research has focused on adapting the Kaiser Score to unenhanced MRI protocols by replacing contrast-dependent parameters with diffusion-based biomarkers while preserving the structured decision-making framework of the original model. [14–17]

The rationale for this adaptation stems from accumulating evidence demonstrating that diffusion-weighted imaging and apparent diffusion coefficient measurements provide diagnostic information comparable to, and in some situations complementary to, dynamic contrast-enhanced MRI. Several studies have shown that ADC values can effectively differentiate benign from malignant breast lesions because malignant tumors generally exhibit restricted diffusion and lower ADC values. These findings have encouraged investigators to explore whether diffusion parameters could substitute for kinetic curve analysis within the Kaiser Score algorithm. [8,15,16]

In the original Kaiser Score, enhancement curve type represents one of the most influential decision nodes because it reflects tumor vascularity and permeability. Malignant lesions frequently demonstrate plateau or washout kinetics, whereas benign lesions often show persistent enhancement. Since enhancement curves are unavailable in unenhanced MRI, modified Kaiser models have proposed replacing this variable with ADC-based assessment. This modification allows diffusion restriction to serve as a surrogate marker of malignancy, thereby maintaining the functional component of the diagnostic pathway despite the absence of contrast administration. [6,15,17]

The modified unenhanced Kaiser Score retains the fundamental principle of the original model by integrating morphological and functional imaging features into a structured decision tree. Lesion margins remain the most important discriminator, with irregular or spiculated margins strongly favoring malignancy. Additional assessment includes lesion morphology, T2-weighted signal characteristics, edema, DWI appearance, and ADC measurements. By combining these parameters, the modified score preserves the hierarchical diagnostic logic that has contributed to the success of the conventional Kaiser Score. [13,17]

Particular emphasis is placed on ADC values because they provide objective quantitative information that can be incorporated into decision-making. Lesions demonstrating low ADC values consistent with restricted diffusion are assigned greater suspicion, especially when accompanied by irregular morphology or non-circumscribed margins. Conversely, lesions with benign morphology and relatively high ADC values may be downgraded, reducing unnecessary biopsy recommendations. This integration of qualitative and quantitative imaging findings represents one of the principal strengths of the modified Kaiser approach. [15,31]

An important contribution to this field was provided by Pötsch and colleagues, who proposed a dedicated decision tree specifically designed for unenhanced breast MRI. Their model incorporated lesion margins, diffusion characteristics, ADC values, and T2-weighted features while eliminating dependence on contrast-enhancement kinetics. The proposed algorithm maintained the practical simplicity of the original Kaiser Score and demonstrated encouraging diagnostic performance for differentiating benign and malignant breast lesions. Importantly, the study highlighted the need to recognize diffusion-restricted cancers that may appear morphologically benign, particularly certain triple-negative breast cancers, to avoid false-negative interpretations. [17]

Recent investigations have further supported the integration of diffusion metrics into Kaiser-based assessment models. Studies evaluating the combined use of the Kaiser Score and ADC measurements have reported improvements in specificity and overall diagnostic performance compared with conventional MRI interpretation alone. The addition of quantitative diffusion information appears particularly valuable for lesions categorized as indeterminate or BI-RADS 4, where unnecessary biopsies remain a common clinical problem. These findings suggest that diffusion-enhanced Kaiser models may help refine risk stratification while preserving high cancer detection rates. [14,15]

Another important advantage of adapting the Kaiser Score to unenhanced MRI is its compatibility with abbreviated imaging protocols. As breast MRI screening expands, there is increasing demand for shorter and more cost-effective examinations. A structured unenhanced Kaiser algorithm may facilitate rapid interpretation of DWI- and T2-based protocols while maintaining standardized lesion characterization. Such an approach could improve accessibility to breast MRI, especially in healthcare systems where cost, scanner availability, or contrast administration represent limiting factors. [7,11]

Despite encouraging results, several challenges remain before widespread implementation of the unenhanced Kaiser Score can be recommended. ADC thresholds may vary between MRI systems and institutions, and standardization of DWI acquisition protocols remains an ongoing challenge. In addition, some benign lesions may demonstrate restricted diffusion, whereas certain low-grade or mucinous malignancies may show relatively high ADC values. Therefore, diffusion findings should always be interpreted within the broader morphological context provided by the Kaiser decision tree. [7,26,30]

7. Diagnostic Accuracy of the Kaiser Score in Unenhanced Breast MRI

The adaptation of the Kaiser Score to unenhanced breast MRI has generated considerable interest because it offers the possibility of maintaining the diagnostic advantages of structured MRI interpretation while eliminating the need for gadolinium-based contrast agents. The primary objective of these modified models is to preserve the high sensitivity traditionally associated with breast MRI while improving specificity through the integration of diffusion-weighted imaging and ADC measurements. Recent studies evaluating unenhanced Kaiser-based approaches have reported encouraging results, suggesting that diffusion-derived information can successfully compensate for the absence of enhancement kinetics in many breast lesions. [14–17]

A fundamental measure of any diagnostic model is its ability to accurately differentiate benign from malignant lesions. Evidence from studies investigating modified Kaiser algorithms indicates that the combination of lesion morphology, T2-weighted characteristics, DWI appearance, and ADC values provides strong discriminatory power. Similar to the conventional Kaiser Score, lesion margins remain the most influential morphological predictor of malignancy, while ADC values serve as the principal functional biomarker. The integration of these parameters enables unenhanced Kaiser models to achieve diagnostic performances approaching those reported for contrast-enhanced MRI in selected patient populations. [15–17]

Sensitivity remains one of the major strengths of both conventional and modified Kaiser approaches. Because breast MRI is inherently highly sensitive for breast cancer detection, preservation of sensitivity is essential when transitioning to contrast-free imaging protocols. Studies evaluating unenhanced MRI have demonstrated that malignant lesions frequently exhibit both suspicious morphology and restricted diffusion, allowing them to be correctly classified within modified Kaiser decision pathways. Consequently, most invasive cancers can be identified even in the absence of contrast-enhancement kinetics. [8,10,16]

Specificity is arguably the area where modified Kaiser models may offer their greatest clinical benefit. Conventional breast MRI often identifies numerous enhancing lesions that ultimately prove benign, contributing to unnecessary biopsies and patient anxiety. By incorporating ADC measurements, modified Kaiser algorithms provide an objective quantitative parameter that helps distinguish true malignancies from benign proliferative, inflammatory, or fibrocystic lesions. Several studies have shown that adding ADC information to Kaiser-based assessment improves specificity and may reduce false-positive interpretations without substantially affecting cancer detection rates. [12,14,15]

The role of ADC is particularly important in lesions categorized as intermediate or suspicious on morphological assessment alone. In such cases, diffusion measurements can provide additional evidence supporting either lesion upgrade or downgrade. Low ADC values strengthen suspicion for malignancy, whereas higher ADC values may support benign interpretation when combined with favorable morphological characteristics. This complementary relationship between morphology and diffusion is one of the key reasons why Kaiser-based approaches generally outperform ADC-only strategies and pure subjective interpretation. [15,31]

Receiver operating characteristic (ROC) analyses performed in studies evaluating Kaiser Score modifications have further demonstrated the robustness of structured MRI assessment. Although exact performance values vary according to patient population, MRI protocol, and ADC threshold selection, the overall diagnostic accuracy of modified Kaiser algorithms has consistently been reported as high. The preservation of decision-tree logic appears to allow effective integration of diffusion metrics into a clinically applicable framework, thereby maintaining diagnostic confidence despite the absence of enhancement kinetics. [14,15,17]

An additional strength of unenhanced Kaiser approaches is their potential role in reducing unnecessary biopsies. MRI-detected lesions classified as BI-RADS 4 frequently undergo tissue sampling despite a substantial proportion ultimately proving benign. The integration of diffusion information into Kaiser-based assessment may improve risk stratification of these lesions and facilitate more accurate clinical decision-making. Such an effect could have important implications for healthcare costs, patient anxiety, and procedural burden while maintaining oncologic safety. [12,14,15]

Nevertheless, diagnostic performance remains influenced by several technical and biological factors. Variability in ADC measurements across scanners, differences in acquisition protocols, lesion size, and histological subtype can affect classification accuracy. Certain benign lesions may demonstrate restricted diffusion, while some low-cellularity cancers may exhibit relatively high ADC values. Moreover, special tumor subtypes such as mucinous carcinoma may not follow typical diffusion patterns. These limitations highlight the importance of interpreting ADC values within a comprehensive morphological framework rather than relying on quantitative measurements alone. [26,30]

Comparison with conventional contrast-enhanced MRI suggests that unenhanced Kaiser models have not yet completely replaced the diagnostic capabilities of DCE-MRI. Enhancement kinetics continue to provide valuable biological information regarding tumor vascularity and permeability. However, available evidence indicates that carefully optimized unenhanced protocols incorporating DWI, ADC analysis, and structured Kaiser-based assessment can achieve diagnostic performances sufficiently close to conventional MRI to justify continued investigation and clinical validation. This finding is particularly important in settings where contrast administration is undesirable or impractical. [7,11,16]

Conclusion

The Kaiser Score is a valuable structured tool for breast lesion characterization and has shown strong potential for application in unenhanced breast MRI. By integrating lesion morphology with DWI and ADC-based assessment, modified Kaiser Score models may compensate for the absence of contrast-enhancement kinetics while maintaining reliable differentiation between benign and malignant lesions.

Unenhanced breast MRI offers important advantages, including shorter examination time, lower cost, improved accessibility, and avoidance of gadolinium administration. However, its diagnostic reliability depends on optimized DWI technique, standardized ADC interpretation, and careful correlation with morphological features, the modified Kaiser Score represents a promising step toward standardized contrast-free breast MRI interpretation. Further prospective multicenter studies are still needed to validate diagnostic thresholds, reduce technical variability, and support routine clinical implementation.

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