

Research Article

Utility of Conventional and Advanced Sequences – Dynamic Contrast-Enhanced MRI and DWI/ADC Sequences in Differentiating Benign Versus Malignant Breast Lesions

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Abstract: Introduction: Breast magnetic resonance imaging (MRI) has emerged as a highly sensitive imaging modality for the detection and characterization of breast lesions. Conventional MRI sequences provide excellent morphological assessment, whereas advanced sequences such as Dynamic Contrast-Enhanced MRI (DCE-MRI) and Diffusion Weighted Imaging (DWI) with Apparent Diffusion Coefficient (ADC) mapping improve tissue characterization and lesion differentiation. **Aim:** To evaluate the diagnostic utility of conventional MRI sequences and advanced MRI techniques including DCE-MRI and DWI/ADC sequences in differentiating benign from malignant breast lesions. **Materials and Methods:** A prospective observational study was conducted among 120 female patients presenting with suspicious breast lesions. All patients underwent breast MRI using conventional sequences, DCE-MRI, and DWI/ADC imaging on a 1.5 Tesla MRI scanner. MRI findings were correlated with histopathological examination, which served as the gold standard. Morphological characteristics, enhancement kinetics, diffusion restriction, and ADC values were analyzed. **Results:** Among 120 lesions evaluated, 68 were malignant and 52 were benign. Malignant lesions demonstrated irregular margins, heterogeneous enhancement, type III washout kinetic curves, restricted diffusion, and significantly lower ADC values compared to benign lesions. The mean ADC value of malignant lesions was $0.89 \pm 0.14 \times 10^{-3} \text{ mm}^2/\text{s}$, whereas benign lesions showed a mean ADC value of $1.54 \pm 0.21 \times 10^{-3} \text{ mm}^2/\text{s}$ ($p < 0.001$). Combined use of DCE-MRI and DWI/ADC improved diagnostic accuracy to 95.8%, sensitivity to 97.1%, and specificity to 94.2%. **Conclusion:** Advanced MRI techniques, particularly DCE-MRI combined with DWI/ADC mapping, significantly enhance the diagnostic accuracy of breast MRI in differentiating benign from malignant lesions. Integration of functional imaging with conventional MRI sequences can reduce unnecessary biopsies and improve early breast cancer diagnosis.

Keywords: Breast MRI, DCE-MRI, Diffusion Weighted Imaging, ADC, Breast cancer, Benign breast lesions

INTRODUCTION

Breast cancer remains the most common malignancy among women worldwide and is a leading cause of cancer-related mortality. Early detection and accurate characterization of breast lesions are essential for improving patient outcomes and survival rates[1]. Conventional imaging modalities such as mammography and ultrasonography are widely used; however, their sensitivity decreases in dense breast tissue and in certain complex lesions[2].

Magnetic Resonance Imaging (MRI) has revolutionized breast imaging due to its superior soft tissue contrast and high sensitivity. Conventional MRI sequences provide detailed anatomical and morphological information regarding lesion shape, margins, and internal characteristics. However, morphological assessment

alone may not reliably distinguish benign from malignant lesions because of overlapping imaging appearances[3].

Advanced MRI techniques such as Dynamic Contrast-Enhanced MRI (DCE-MRI) and Diffusion Weighted Imaging (DWI) have significantly improved lesion characterization. DCE-MRI evaluates vascularity and permeability changes associated with tumor angiogenesis by analyzing enhancement kinetics after gadolinium administration. Malignant lesions typically demonstrate rapid initial enhancement followed by washout kinetics[4].

Diffusion Weighted Imaging evaluates the mobility of water molecules within tissues. Malignant lesions usually show restricted diffusion because of high cellular density and reduced extracellular space. Apparent

Diffusion Coefficient (ADC) values quantitatively assess diffusion restriction and help differentiate malignant from benign lesions[5].

Several studies have demonstrated the incremental value of combining conventional MRI with functional imaging techniques. Nevertheless, variability in ADC cutoff values and enhancement patterns necessitates further evaluation in different populations.

The present study was undertaken to assess the utility of conventional MRI and advanced MRI sequences in differentiating benign from malignant breast lesions and to determine their diagnostic performance using histopathology as the reference standard.

Aim and Objectives

Aim

To evaluate the utility of conventional MRI sequences and advanced sequences including DCE-MRI and DWI/ADC in differentiating benign from malignant breast lesions.

Objectives

1. To assess morphological characteristics of breast lesions on conventional MRI.
2. To evaluate enhancement kinetic patterns on DCE-MRI.
3. To determine ADC values in benign and malignant lesions.
4. To compare MRI findings with histopathological diagnosis.
5. To calculate sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of MRI sequences.

MATERIALS AND METHODS

Study Design and Study Setting

This prospective observational study was conducted in the Department of Radiodiagnosis at Dr Chandramma Dayananda Sagar Institute of Medical Education and Research, located at Devarakaggalahalli, Harohalli, Kanakapura Main Road, Karnataka, India. The study was carried out in collaboration with the Departments of General Surgery and Pathology of the same institution. The research was conducted over a period of 12 months from January 2025 to December 2025 after obtaining approval from the Institutional Ethics Committee and informed written consent from all participating patients.

The study included female patients who were referred to the Department of Radiodiagnosis with clinically suspected breast lesions or imaging abnormalities detected on mammography and ultrasonography. A total of 120 female patients with suspicious breast lesions were enrolled consecutively during the study period. All patients underwent detailed clinical evaluation followed by breast MRI examination using conventional MRI sequences along with advanced imaging techniques

including Dynamic Contrast-Enhanced Magnetic Resonance Imaging (DCE-MRI) and Diffusion Weighted Imaging (DWI) with Apparent Diffusion Coefficient (ADC) mapping. Histopathological examination obtained through core needle biopsy, excisional biopsy, or surgical specimen analysis served as the gold standard for final diagnosis.

Female patients aged more than 18 years presenting with palpable breast lumps, suspicious breast lesions detected on mammography or ultrasonography, nipple discharge, focal breast pain associated with imaging abnormalities, or clinically suspected breast malignancy were included in the study. Patients who were willing to undergo MRI examination and subsequent histopathological confirmation were recruited after obtaining informed consent.

Patients with contraindications to MRI such as cardiac pacemakers, cochlear implants, ferromagnetic implants, severe claustrophobia, or metallic foreign bodies were excluded from the study. Pregnant women were excluded because of concerns regarding gadolinium administration and MRI safety during pregnancy. Patients with prior breast surgery, radiotherapy, chemotherapy, or previously diagnosed breast malignancy undergoing treatment were also excluded to avoid post-treatment imaging alterations that could interfere with interpretation. Additionally, patients with known hypersensitivity or allergic reactions to gadolinium-based contrast agents and those with severe renal impairment were excluded from participation.

All MRI examinations were performed using a dedicated 1.5 Tesla breast MRI system with patients positioned prone using a dedicated bilateral breast coil. Conventional MRI sequences included axial T1-weighted imaging, axial and sagittal T2-weighted imaging, and STIR sequences for lesion localization and morphological assessment. Dynamic contrast-enhanced MRI was performed following intravenous administration of gadolinium contrast at a dose of 0.1 mmol/kg body weight, followed by serial post-contrast imaging to evaluate enhancement characteristics and kinetic curves. Diffusion weighted imaging was obtained using multiple b values (0, 500, and 1000 s/mm²), and ADC maps were generated automatically for quantitative analysis.

MRI findings were analyzed based on lesion morphology, margin characteristics, enhancement patterns, kinetic curve analysis, diffusion restriction, and ADC values. Lesions were categorized as benign or malignant based on imaging characteristics and subsequently correlated with histopathological diagnosis. Statistical analysis was performed using SPSS software version 26.0, and diagnostic indices including sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic

accuracy were calculated. A p-value of less than 0.05 was considered statistically significant.

MRI Protocol

All MRI examinations were performed in the Department of Radiodiagnosis at Dr Chandramma Dayananda Sagar Institute of Medical Education and Research using a dedicated 1.5 Tesla breast MRI system equipped with a dedicated bilateral phased-array breast coil. Patients were positioned prone to allow optimal visualization of both breasts and to minimize motion artifacts during image acquisition. Prior to imaging, all patients were screened for contraindications to MRI and gadolinium-based contrast administration.

The MRI protocol included both conventional anatomical sequences and advanced functional imaging sequences for comprehensive lesion evaluation. Conventional MRI sequences consisted of axial T1-weighted imaging, axial and sagittal T2-weighted imaging, and Short Tau Inversion Recovery (STIR) sequences. These sequences were used to assess lesion morphology, signal characteristics, surrounding breast parenchyma, skin involvement, chest wall extension, and axillary lymphadenopathy. T1-weighted images helped identify hemorrhage, fat content, and architectural distortion, while T2-weighted and STIR sequences were useful in evaluating lesion internal characteristics, edema, cystic changes, and inflammatory components. Advanced imaging included Dynamic Contrast-Enhanced Magnetic Resonance Imaging (DCE-MRI) and Diffusion Weighted Imaging (DWI) with Apparent Diffusion Coefficient (ADC) mapping. For DCE-MRI, gadolinium-based intravenous contrast was administered at a dose of 0.1 mmol/kg body weight using a power injector, followed by a saline flush. Sequential post-contrast images were acquired at multiple time intervals to evaluate the enhancement characteristics of breast lesions. Enhancement kinetics were analyzed using time–signal intensity curves and categorized into persistent (Type I), plateau (Type II), and washout (Type III) patterns. Morphological features including lesion shape, margins, internal enhancement pattern, and enhancement symmetry were also assessed according to the Breast Imaging Reporting and Data System (BI-RADS) MRI lexicon.

Diffusion Weighted Imaging was performed using echo-planar imaging sequences with b values of 0, 500, and 1000 s/mm². DWI was used to evaluate the diffusion characteristics of breast lesions based on the movement of water molecules within tissues. Apparent Diffusion Coefficient (ADC) maps were automatically generated by the MRI workstation software, and ADC values were calculated by placing regions of interest (ROIs) over the solid components of the lesions while avoiding necrotic or cystic areas. Lesions showing restricted diffusion with low ADC values were considered suggestive of malignancy, whereas lesions with facilitated diffusion and higher ADC values were considered more likely

benign. The combined interpretation of conventional MRI, DCE-MRI, and DWI/ADC findings was used for lesion characterization and diagnostic assessment.

MRI Interpretation Criteria

All MRI examinations were interpreted independently by experienced radiologists in the Department of Radiodiagnosis at Dr Chandramma Dayananda Sagar Institute of Medical Education and Research using the Breast Imaging Reporting and Data System (BI-RADS) MRI lexicon. Interpretation of breast lesions was based on a combination of conventional morphological assessment, dynamic contrast enhancement characteristics, and diffusion-weighted imaging findings.

Morphological evaluation of lesions was performed on conventional and post-contrast MRI sequences. Lesion characteristics analyzed included shape, margins, internal enhancement pattern, presence of septations, and associated skin involvement. Lesions with smooth, oval, or round morphology and well-circumscribed margins were generally considered suggestive of benign pathology, whereas lesions demonstrating irregular shape, spiculated or ill-defined margins were considered suspicious for malignancy. Internal enhancement patterns such as homogeneous enhancement were more commonly associated with benign lesions, while heterogeneous or rim enhancement patterns were considered more indicative of malignant lesions. The presence of thick septations, architectural distortion, skin thickening, nipple retraction, or chest wall invasion was also carefully assessed, as these features favored malignant etiology.

Dynamic Contrast-Enhanced MRI (DCE-MRI) findings were analyzed by evaluating the enhancement kinetics of lesions using time–signal intensity curves obtained from sequential post-contrast imaging. Enhancement patterns were classified into three kinetic curve types. Type I curves demonstrated persistent progressive enhancement over time and were generally considered suggestive of benign lesions. Type II curves showed an initial rapid enhancement followed by a plateau phase and were categorized as indeterminate or suspicious lesions. Type III curves exhibited rapid initial enhancement followed by delayed washout of contrast material and were considered highly suggestive of malignancy due to increased tumor angiogenesis and abnormal vascular permeability.

Diffusion Weighted Imaging (DWI) and Apparent Diffusion Coefficient (ADC) mapping were used for functional assessment of tissue cellularity. Lesions demonstrating restricted diffusion on DWI with corresponding low ADC values were considered suggestive of malignancy because of increased cellular density and reduced extracellular space. ADC measurements were obtained by placing regions of interest over the solid enhancing portions of the lesion

while avoiding necrotic, hemorrhagic, or cystic areas. Lesions with facilitated diffusion and higher ADC values were more likely to represent benign pathology. Final MRI interpretation was based on combined assessment of morphological features, enhancement kinetics, and

diffusion characteristics to improve diagnostic accuracy in differentiating benign and malignant breast lesions.

RESULTS

Age Distribution of Study Participants

Table 1 shows a total of 120 female patients were included in the study. Benign breast lesions were more commonly observed in younger patients, particularly in the 20–40 years age group, whereas malignant lesions were predominantly seen in patients above 40 years of age. The highest number of malignant lesions was noted in the 41–50 years age group (28 cases). Overall, the mean age of patients with malignant breast lesions was significantly higher than that of patients with benign lesions, suggesting an increased incidence of malignancy with advancing age.

Table:1 Age Distribution

Age Group (Years)	Benign	Malignant	Total
20–30	18	4	22
31–40	16	12	28
41–50	10	28	38
51–60	6	18	24
>60	2	6	8

Mean age of malignant cases was significantly higher.

Morphological Characteristics of Breast Lesions on MRI

Morphological assessment of breast lesions on MRI demonstrated significant differences between benign and malignant lesions. Smooth margins were predominantly observed in benign lesions (84.6%), whereas only 10.2% of malignant lesions showed smooth margins. In contrast, irregular margins were highly associated with malignant lesions, being present in 89.8% of malignant cases compared to 15.4% of benign lesions.

Regarding internal enhancement patterns, homogeneous enhancement was more commonly seen in benign lesions (76.9%), while heterogeneous enhancement was predominantly observed in malignant lesions (85.3%). The differences in margin characteristics and enhancement patterns between benign and malignant lesions were statistically highly significant ($p < 0.001$), indicating the important role of morphological MRI features in differentiating breast lesions.

Table 2:Morphological Characteristics

MRI Feature	Benign (%)	Malignant (%)	p-value
Smooth margins	84.6	10.2	<0.001
Irregular margins	15.4	89.8	<0.001
Homogeneous enhancement	76.9	14.7	<0.001
Heterogeneous enhancement	23.1	85.3	<0.001

DCE-MRI Kinetic Patterns

Dynamic contrast-enhanced MRI analysis showed distinct enhancement kinetic patterns between benign and malignant breast lesions. Type I persistent enhancement curves were predominantly observed in benign lesions, accounting for 38 cases, while only 4 malignant lesions demonstrated this pattern. Type II plateau curves were seen in 10 benign and 12 malignant lesions, representing an indeterminate enhancement pattern. Type III washout curves were strongly associated with malignancy and were observed in 52 malignant lesions compared to only 4 benign lesions. These findings indicate that Type III washout kinetics have a strong correlation with malignant breast lesions and serve as an important indicator in differentiating benign from malignant pathology.

Table 3:DCE-MRI Kinetic Patterns

Kinetic Curve Type	Benign	Malignant
Type I	38	4
Type II	10	12
Type III	4	52

Type III washout kinetics strongly correlated with malignancy.

ADC Values of Breast Lesions

Diffusion-weighted imaging with ADC mapping demonstrated significant differences between benign and malignant breast lesions. Benign lesions showed a higher mean ADC value of $1.54 \pm 0.21 \times 10^{-3} \text{ mm}^2/\text{s}$, whereas malignant lesions demonstrated significantly lower mean ADC values of $0.89 \pm 0.14 \times 10^{-3} \text{ mm}^2/\text{s}$. The reduced ADC values in malignant lesions reflected increased cellularity and restricted diffusion within tumor tissue. The difference in ADC values between benign and malignant lesions was statistically highly significant ($p < 0.001$), highlighting the important role of ADC measurement in differentiating breast lesions.

Table 4:ADC Values

Lesion Type	Mean ADC Value ($\times 10^{-3} \text{ mm}^2/\text{s}$)
Benign	1.54 ± 0.21
Malignant	0.89 ± 0.14

Difference statistically significant ($p < 0.001$).

Diagnostic Performance of MRI Techniques

The diagnostic performance of various MRI techniques was evaluated in differentiating benign and malignant breast lesions. Conventional MRI demonstrated a sensitivity of 82.4%, specificity of 78.8%, and overall diagnostic accuracy of 80.8%. Dynamic Contrast-Enhanced MRI (DCE-MRI) showed improved diagnostic performance with sensitivity, specificity, and accuracy of 91.2%, 88.5%, and 89.9%, respectively.

Diffusion Weighted Imaging with ADC mapping further enhanced lesion characterization, demonstrating a sensitivity of 94.1%, specificity of 90.4%, and diagnostic accuracy of 92.5%. The highest diagnostic performance was achieved when conventional MRI, DCE-MRI, and DWI/ADC findings were combined, resulting in a sensitivity of 97.1%, specificity of 94.2%, and overall diagnostic accuracy of 95.8%. These findings indicate that multiparametric breast MRI significantly improves the differentiation of benign and malignant breast lesions compared to conventional MRI alone.

Table 5:Diagnostic Performance

MRI Technique	Sensitivity	Specificity	Accuracy
Conventional MRI	82.4%	78.8%	80.8%
DCE-MRI	91.2%	88.5%	89.9%
DWI/ADC	94.1%	90.4%	92.5%
Combined MRI	97.1%	94.2%	95.8%

Figure 1. Flow Diagram of Study Methodology

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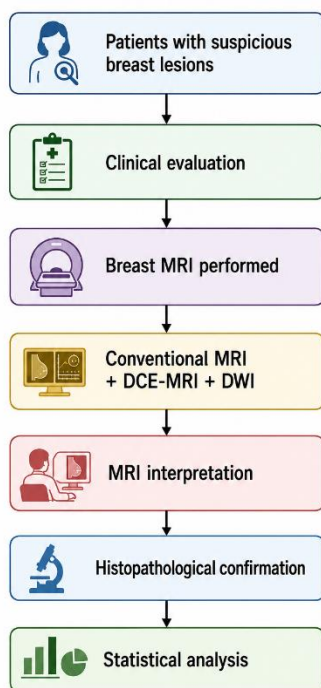


Figure 1 illustrates the overall methodology adopted in the present study for evaluating the role of conventional MRI and advanced MRI sequences in differentiating benign and malignant breast lesions. The study began with the inclusion of patients presenting with suspicious breast lesions based on clinical examination or prior imaging findings. All patients subsequently underwent detailed clinical evaluation followed by breast MRI examination. The MRI protocol included conventional MRI sequences along with advanced imaging techniques such as Dynamic Contrast-Enhanced MRI (DCE-MRI) and Diffusion Weighted Imaging (DWI) with ADC mapping. The acquired MRI images were interpreted based on morphological features, enhancement kinetics, and diffusion characteristics. Final imaging diagnoses were correlated with histopathological examination, which served as the gold standard. Statistical analysis was then performed to determine the diagnostic performance of the MRI techniques.

Figure 2. Typical MRI Features

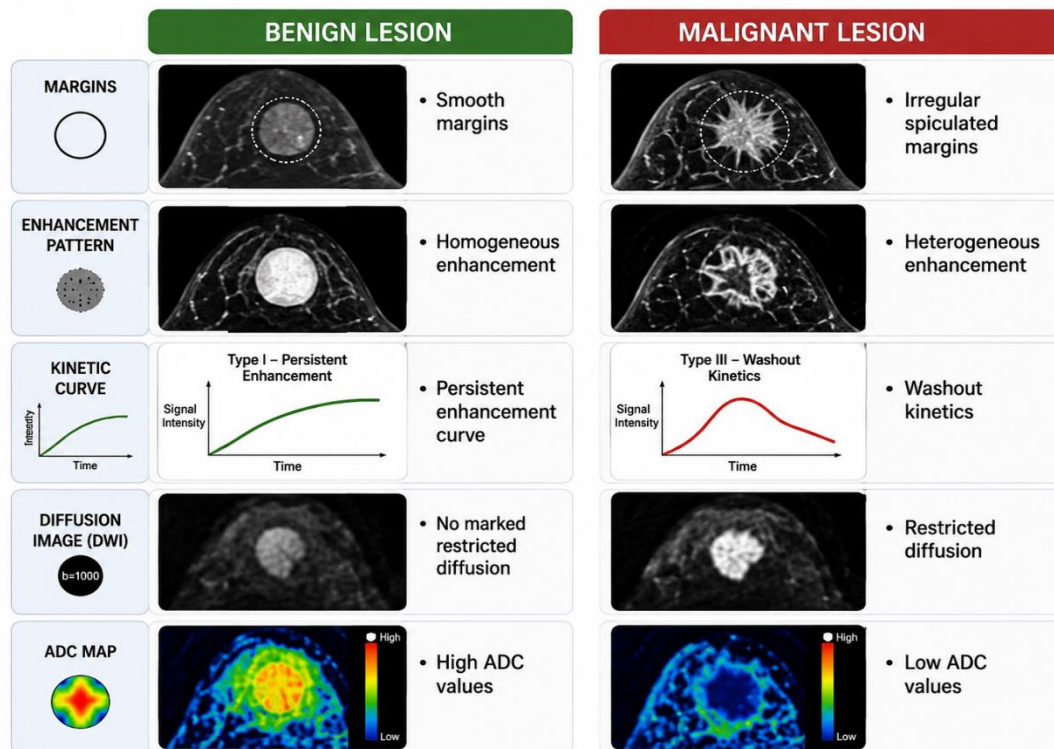


Figure 2 demonstrates the characteristic MRI features observed in benign and malignant breast lesions. Benign lesions typically appear as well-defined masses with smooth margins and homogeneous internal enhancement on contrast-enhanced MRI. These lesions commonly exhibit persistent enhancement kinetics (Type I curve) on DCE-MRI and show no significant diffusion restriction on DWI, resulting in relatively high ADC values.

In contrast, malignant breast lesions usually demonstrate irregular or spiculated margins with heterogeneous internal enhancement patterns. On DCE-MRI, malignant lesions characteristically exhibit rapid contrast uptake followed by washout kinetics (Type III curve), reflecting increased tumor vascularity and permeability. Diffusion Weighted Imaging shows marked restricted diffusion in malignant lesions due to high cellular density, and corresponding ADC maps reveal low ADC values. These combined morphological and functional MRI features aid significantly in differentiating benign from malignant breast lesions.

Benign Lesion

- Smooth margins
- Homogeneous enhancement
- Persistent enhancement curve
- High ADC values

Malignant Lesion

- Irregular spiculated margins
- Heterogeneous enhancement
- Washout kinetics

- Restricted diffusion
- Low ADC values

DISCUSSION

MRI has become an indispensable tool in breast imaging because of its excellent sensitivity for lesion detection. However, specificity remains a challenge when relying solely on conventional morphological criteria. The addition of functional imaging techniques such as DCE-MRI and DWI substantially improves diagnostic confidence[6].

In the present study, malignant lesions commonly demonstrated irregular margins and heterogeneous enhancement, which is consistent with previous literature[7]. Tumor angiogenesis leads to abnormal vascular permeability, resulting in rapid contrast uptake and washout kinetics on DCE-MRI[8].

The findings of this study revealed that Type III washout curves were highly associated with malignancy, similar to studies by Kuhl et al. and Tozaki et al. Persistent enhancement patterns were predominantly observed in benign lesions such as fibroadenomas and fibrocystic disease[9].

Diffusion weighted imaging proved highly valuable in lesion characterization. Malignant lesions exhibited significantly lower ADC values compared to benign lesions due to increased cellularity and restricted extracellular diffusion. The mean ADC value observed in malignant lesions in this study closely parallels values reported in earlier studies[10].

Combining DCE-MRI with DWI/ADC significantly improved diagnostic accuracy. This combination reduces false-positive interpretations and unnecessary biopsies while maintaining high sensitivity for cancer detection[8].

The study findings support the growing role of multiparametric breast MRI in clinical practice. Functional imaging biomarkers can aid radiologists in improving lesion characterization, treatment planning, and monitoring therapeutic response.

Limitations

The present study had certain limitations that should be considered while interpreting the findings. Since the study was conducted at a single tertiary care center, the results may not be fully generalizable to the broader population. The sample size was relatively limited, which may have affected the statistical power and representation of less common breast lesions. Additionally, long-term follow-up of patients was not performed, limiting assessment of disease progression, recurrence, and long-term diagnostic outcomes. Interobserver variability among radiologists interpreting MRI findings was also not evaluated, which could influence the reproducibility and consistency of imaging

interpretation. Despite these limitations, the study provides valuable insight into the role of conventional and advanced MRI sequences in breast lesion characterization.

CONCLUSION

Advanced MRI sequences including DCE-MRI and DWI/ADC significantly improve the differentiation of benign and malignant breast lesions compared to conventional MRI alone. Malignant lesions characteristically show irregular morphology, washout enhancement kinetics, restricted diffusion, and low ADC values.

The combined use of conventional MRI with DCE-MRI and DWI/ADC enhances sensitivity, specificity, and overall diagnostic accuracy. Multiparametric breast MRI should therefore be considered an essential component in the evaluation of suspicious breast lesions.

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