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Research Article

Diagnostic Accuracy of Diffusion-Weighted MRI in Differentiating Benign and Malignant Breast Lesions with Histopathological Correlation

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ABSTRACT

Background: Breast MRI is highly sensitive but has limited specificity. Diffusion-weighted imaging (DWI) with apparent diffusion coefficient (ADC) mapping may improve lesion characterization.
Aim: To evaluate the diagnostic accuracy of DWI in differentiating benign and malignant breast lesions using histopathology as the reference standard.
Materials and Methods: Sixty female patients (18–70 years) with suspected breast lesions underwent MRI with DWI on a 1.5T scanner. ADC values were obtained and correlated with histopathology. Diagnostic indices were calculated, and $p < 0.05$ was considered significant.
Results: Of 60 lesions, 34 (56.7%) were malignant and 26 (43.3%) were benign. Malignant lesions showed significantly lower mean ADC values ($0.92 \pm 0.12 \times 10^{-3}$ mm²/s) compared to benign lesions ($1.58 \pm 0.21 \times 10^{-3}$ mm²/s) ($p < 0.001$). Using an ADC cut-off of 1.13×10^{-3} mm²/s, sensitivity, specificity, and diagnostic accuracy were 94.1%, 88.5%, and 91.7%, respectively.
Conclusion: DWI with ADC quantification is a reliable non-invasive tool that improves sensitivity in breast lesion characterization and may reduce biopsies.

Keywords: *Diffusion-weighted imaging; Breast MRI; Apparent diffusion coefficient; Breast lesions; Breast cancer; Histopathological correlation; Diagnostic accuracy; ADC cut-off; Benign and malignant breast lesions.*

INTRODUCTION

Breast cancer remains the most common malignancy among women worldwide and a leading cause of cancer-related mortality, with rising incidence across both developed and developing nations. Early detection and accurate lesion characterization are essential for improving survival outcomes and guiding appropriate management strategies (1,2). Conventional imaging modalities such as mammography and ultrasonography are widely used; however, their diagnostic accuracy is limited, particularly in patients with dense breast tissue and in cases where benign and malignant lesions exhibit overlapping imaging features (2,3).

Magnetic resonance imaging (MRI) has emerged as a highly sensitive imaging modality for the detection of breast lesions due to its superior soft tissue contrast and ability to assess vascular characteristics using dynamic contrast-enhanced techniques. However, despite its high sensitivity, MRI has relatively lower specificity, often resulting in false-positive findings and unnecessary biopsies (4,5). This limitation highlights the need for adjunct functional imaging techniques to improve diagnostic confidence.

Diffusion-weighted imaging (DWI) is a functional MRI technique that evaluates the Brownian motion of water molecules within tissues. The apparent diffusion coefficient (ADC) quantitatively reflects the degree of water diffusion and is influenced by tissue cellularity and membrane integrity. Malignant lesions typically demonstrate increased cellularity and reduced extracellular space, resulting in restricted diffusion and lower ADC values, whereas benign lesions show higher ADC values due to less restriction (3,6,7).

DWI offers several advantages, including lack of ionizing radiation, shorter acquisition time, and no requirement for contrast administration, making it particularly useful in patients with contraindications to contrast agents. Additionally, ADC values serve as a quantitative biomarker for lesion characterization and may reduce unnecessary biopsies (8–10). However, variability in ADC thresholds and overlap in certain pathological conditions necessitate further evaluation and correlation with histopathology.

The present study aims to assess the diagnostic accuracy of diffusion-weighted MRI in differentiating benign and malignant breast lesions using ADC values and correlating them with histopathological findings.

Aim and Objectives
To evaluate the diagnostic accuracy of Diffusion Weighted Imaging (DWI) in differentiating benign from malignant breast lesions using histopathology as the reference standard, including determination of an optimal ADC cut-off value.

Materials and Methods
This diagnostic accuracy study was conducted in the Department of Radio-Diagnosis, Gadag Institute of Medical Sciences, over two years (March 2024–February 2026). Sixty female patients (18–70 years) with palpable breast lumps, sonographically identified lesions were included using purposive sampling. Patients with very small lesions unsuitable for ROI placement, MRI contraindications, or lack of histopathological correlation were excluded.

All patients underwent breast MRI on a 1.5 Tesla scanner (with diffusion-weighted imaging (DWI). Apparent diffusion coefficient (ADC) maps were generated and region of interest was placed within lesions to obtain ADC values.A circular ROI was placed on the solid enhancing portion of the lesion, avoiding necrotic, hemorrhagic, and cystic areas; mean ADC values were recorded. Imaging findings were correlated with histopathology as the reference standard.

Statistical analysis was performed using SPSS software. Sensitivity and specificity were calculated, and quantitative variables were compared using the unpaired t-test. A p value < 0.05 was considered statistically significant.

RESULTS
A total of 60 female patients presenting with breast lesions were included in the study with ages ranging from 18 to 70 years.(Table 1). The most common presenting complaint was a palpable breast lump, with a subset of patients also reporting associated symptoms such as breast pain, nipple discharge, and skin changes. Histopathological examination, which served as the reference standard, revealed that 34 lesions (56.7%) were malignant and 26 lesions (43.3%) were benign.(Table 2)

Diffusion-weighted imaging demonstrated distinct differences in diffusion characteristics between benign and malignant lesions. Malignant lesions consistently showed restricted diffusion, whereas benign lesions exhibited relatively facilitated diffusion. Quantitative analysis using apparent diffusion coefficient (ADC) values revealed that malignant lesions had a significantly lower mean ADC value ($0.92 \pm 0.12 \times 10^{-3}$ mm²/s) compared to benign lesions ($1.58 \pm 0.21 \times 10^{-3}$ mm²/s), and this difference was found to be statistically highly significant ($p < 0.001$).(Table 3)

Using an ADC cut-off value of 1.13×10^{-3} mm²/s for differentiating malignant from benign lesions, diffusion-weighted MRI demonstrated high diagnostic performance. The sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy were 94.1%, 88.5%, 91.4%, 92.0%, and 91.7%, respectively. Furthermore, a statistically significant inverse correlation was observed between ADC values and malignancy, with lower ADC values being strongly associated with malignant histopathology.(Table 4).(Figure 1).

Representative cases demonstrating diffusion characteristics of benign, borderline, and malignant breast lesions are illustrated in Figure 2-4.

Overall, diffusion-weighted MRI with ADC quantification showed excellent agreement with histopathological findings and proved to be a reliable non-invasive modality for differentiating benign and malignant breast lesions.

Table 1: Table: Distribution of Lesions According to Age Group and Disease Categorization

Histopathological Diagnosis	20–30 yrs	31–40 yrs	41–50 yrs	51–60 yrs	61–70 yrs	Total
Fibroadenoma	3	7	6	1	0	17
Fibrocystic Disease	1	0	3	0	0	4
Ductal Papilloma	0	0	2	0	0	2
Benign Phyllodes Tumor	1	1	0	0	0	2
Invasive Ductal Carcinoma (IDC)	0	0	4	17	9	30
Invasive Lobular Carcinoma (ILC)	0	0	1	3	1	5
Total	**5**	**8**	**16**	**21**	**10**	**60**

Table 2: Distribution of lesions based on DW MRI

DW MRI Impression	Frequency	Percentage
Benign	25	41.7

Malignant	35	58.3
Total	**60**	**100.0**

The table shows the distribution of diffusion-weighted MRI impressions among the 60 study participants. DW MRI categorized 35 lesions (58.3%) as malignant and 25 lesions (41.7%) as benign.

Table 3: Association Between ADC Cut-off Value (1.13 $\times 10^{-3}$ mm²/s) and Histopathology

Histopathology	**ADC <1.13**	**ADC ≥1.13**	**Total**
Malignant	32	2	34
Benign	3	23	26
Total	**35**	**25**	**60**

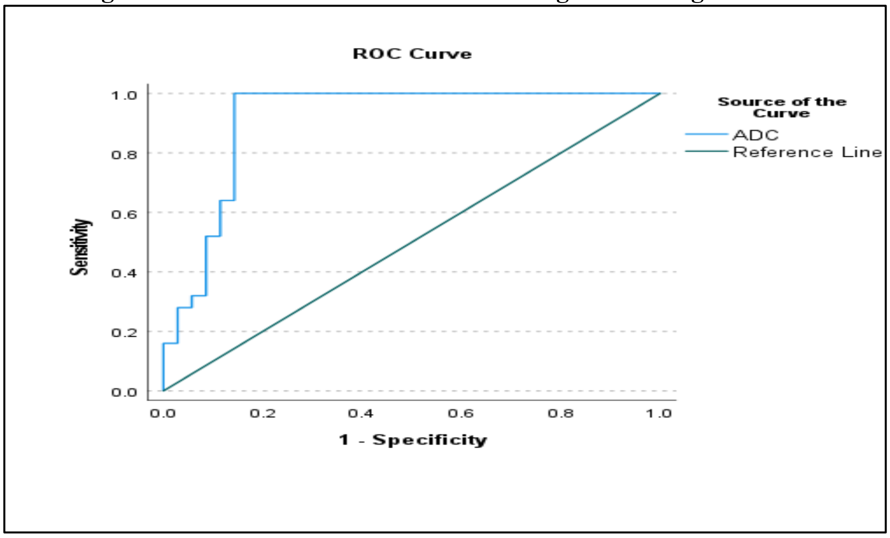
Chi-square value: 31.84
p value:<0.001*
*p value <0.05; statistically significant.

Table 4 : Table: ADC Value Range in Different Histopathological Conditions

Histopathological Diagnosis	**ADC Value Range ($\times 10^{-3}$ mm²/s)**	**Mean ADC Approx.**	**DWI Category**
Fibroadenoma	**1.14 – 2.17**	~1.63	Benign
Fibrocystic disease	**1.14 – 1.88**	~1.56	Benign
Ductal Papilloma	**1.26 – 1.38**	~1.32	Benign
Benign Phyllodes Tumor	**1.28 – 1.49**	~1.39	Benign
Invasive Ductal Carcinoma (IDC)	**0.41 – 1.95**	~0.90	Malignant
Invasive Lobular Carcinoma (ILC)	**0.42 – 1.55**	~0.87	Malignant

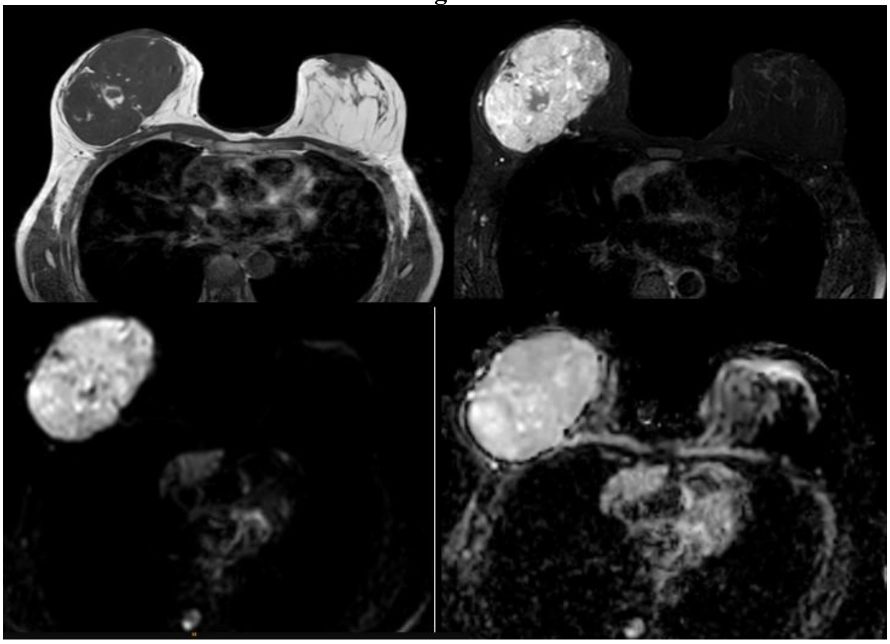
*p value <0.05; hence statistically significant.

Figure 1 Roc curve of ADC value and benign and malignant lesio



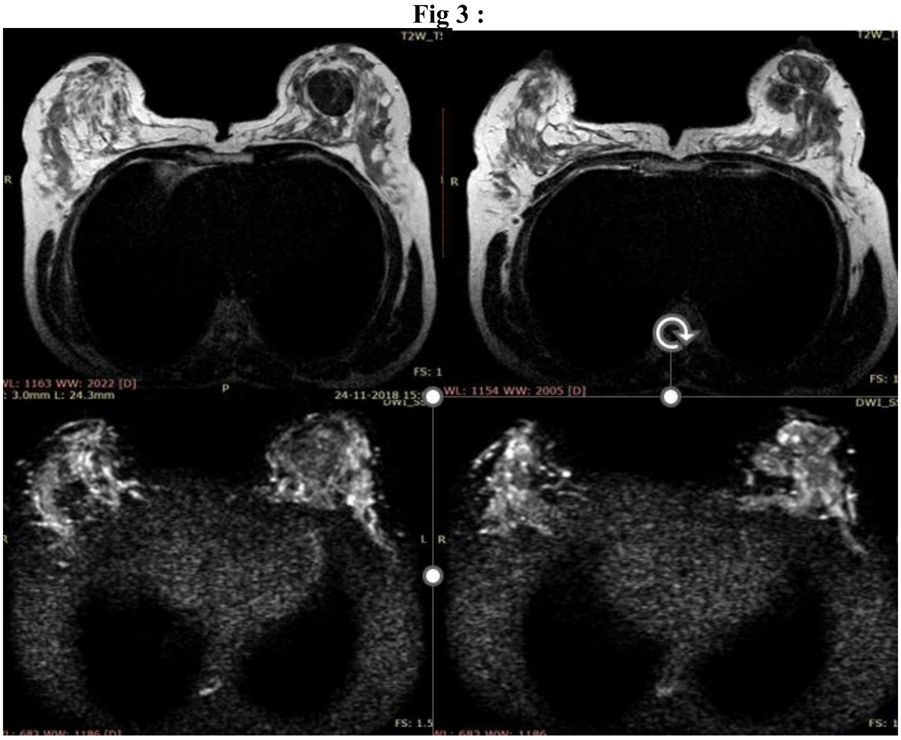
Area under the curve was 0.912
The cut off value of 1.13 was found to have 96.0% sensitivity and 85.7% specificity.

Fig 2:



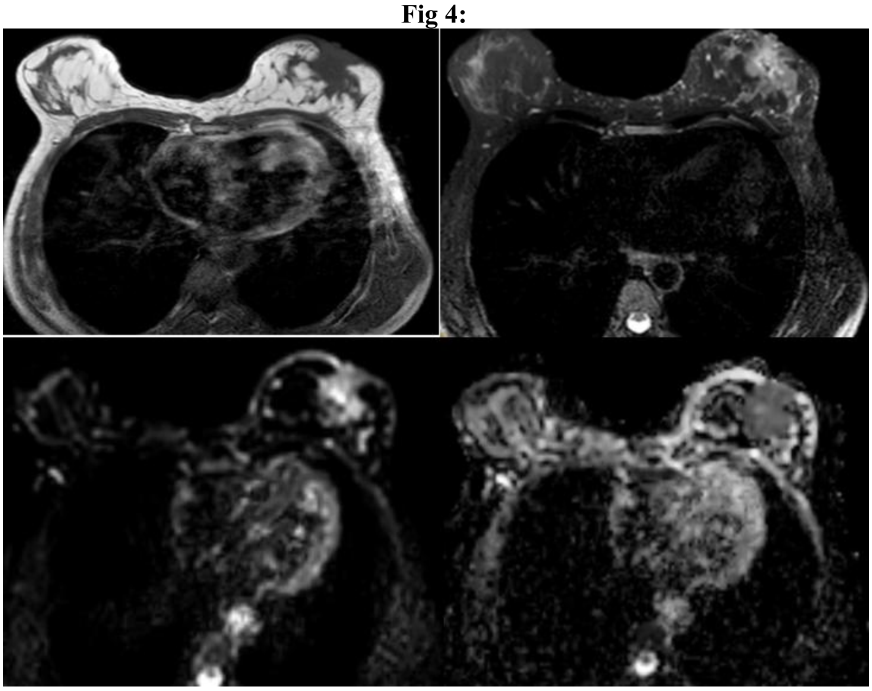
A 40-year-old female presented with a palpable right breast lump. MRI revealed a large encapsulated lesion involving the central, upper outer, and lower quadrants, appearing hypointense on T1 and lobulated with heterogeneous hypo- and hyperintensity on T2 SPAIR, with subtle diffusion restriction; it extended anteriorly to the subcutaneous plane and abutted the pectoralis muscle posteriorly with preserved fat plane. Histopathological evaluation confirmed the diagnosis of a phyllodestumour.

Fig 3 :



A 32-year-old female with left breast lump. MRI revealed a well-defined T1 hypointense, T2 is to hyperintense lesion with no obvious diffusion restriction. On histopathology, the lesion was found to be a fibroadenoma.

Fig 4:



64-year-old female with left breast lump. On MRI, spiculated mass lesion is seen in the left breast beneath the nipple areolar complex. It appears hypointense on T1-weighted images and heterogeneously hyperintense on T2 sequence. The lesion shows diffusion restriction with corresponding low signal on ADC map. On histopathology, the lesion was found to be Invasive ductal carcinoma.

DISCUSSION

Accurate differentiation between benign and malignant breast lesions remains a major challenge in breast imaging, as it directly influences clinical management and helps avoid unnecessary invasive procedures. Although contrast-enhanced MRI is highly sensitive, its specificity is limited due to overlapping enhancement characteristics between benign and malignant lesions [8,9]. Diffusion-weighted imaging (DWI), by providing functional information based on water molecule diffusion, has emerged as a valuable adjunct in improving lesion characterization.

In the present study, malignant lesions demonstrated significantly lower ADC values compared to benign lesions. The mean ADC value of malignant lesions ($0.92 \pm 0.12 \times 10^{-3}$ mm²/s) was significantly lower than that of benign lesions ($1.58 \pm 0.21 \times 10^{-3}$ mm²/s), which is consistent with previously published studies. [10,11]. This difference can be attributed to the increased cellularity, reduced extracellular space, and higher nuclear-to-cytoplasmic ratio seen in malignant tumors, leading to restricted diffusion of water molecules [12].

Using an ADC cut-off value of 1.2×10^{-3} mm²/s, this study demonstrated high diagnostic performance, with sensitivity of 94.1%, specificity of 88.5%, and overall diagnostic accuracy of 91.7%. These findings are comparable to earlier studies, which have reported sensitivity ranging from 85% to 95% and specificity between 80% and 90% [11,13]. A meta-analysis by Dorrius et al. also highlighted that the addition of DWI to conventional MRI significantly improves specificity without compromising sensitivity [13].

A statistically significant inverse correlation between ADC values and malignancy was observed in this study, reinforcing the role of ADC as a reliable quantitative biomarker. Lower ADC values were strongly associated with malignant lesions, supporting the biological premise that tumor cellularity restricts water diffusion [12,14]. This quantitative approach enhances diagnostic confidence and provides an objective parameter that complements morphological and kinetic MRI findings.

Despite its advantages, DWI has certain limitations. Overlap in ADC values may occur in specific histological subtypes such as mucinous carcinoma, which can demonstrate higher ADC values due to mucin content, and in certain benign lesions with high cellularity such as sclerosingadenosis [15]. Additionally, necrosis, hemorrhage, and fibrosis within lesions can influence ADC measurements. Technical factors including ROI placement, b-value selection, and susceptibility artifacts may also affect reproducibility and accuracy [16].

The findings of this study support the incorporation of DWI into routine breast MRI protocols. As a non-contrast technique, DWI is particularly useful in patients with contraindications to gadolinium-based contrast agents and may serve as a cost-effective adjunct, especially in resource-limited settings [17]. When combined with conventional MRI, DWI improves specificity and aids in better lesion characterization, potentially reducing unnecessary biopsies.

CONCLUSION

Diffusion-weighted magnetic resonance imaging with quantitative apparent diffusion coefficient assessment demonstrates high diagnostic accuracy in differentiating benign from malignant breast lesions. Malignant lesions show significantly lower ADC values compared to benign lesions, reflecting underlying differences in tissue cellularity. The use of an ADC cut-off value provides a reliable, objective parameter with high sensitivity and specificity, showing strong correlation with histopathological findings.

DWI serves as a valuable non-invasive adjunct to conventional breast MRI, improving specificity and diagnostic confidence and has the potential to reduce unnecessary biopsies, particularly in indeterminate lesions. Its non-contrast nature further enhances its clinical utility, especially in patients with contraindications to contrast administration. Incorporation of DWI into routine breast MRI protocols is therefore recommended for improved lesion characterization.

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