Original Article

Comparative Evaluation Of Diffusion Weighted MRI And Ultrasonography In The Detection Of Breast Lesions

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Abstract

Objective: To compare the evaluation of diffusion weighted MRI and ultrasonography in the detection of breast lesions.
Study design: It was a Cross-Sectional Comparative Study.
Place and duration of study: The study was conducted at at Islamabad Diagnostic Center, Faisalabad from July 2024 to December 2024.
Material and Methods: A sample size of 97 patients presenting with breast lesions was selected, excluding those with previous breast implant. All patients underwent MRI using a 1.5 Tesla machine and statistical analysis was performed using SPSS version 25.
Results: This study included 97 patients with breast lesions to compare the diagnostic performance of ultrasonography (US) and diffusion-weighted MRI (DWI). Based on US, 39 patients (40.2%) were classified as BI-RADS 2, 32 (33.0%) as BI-RADS 3, 6 (6.2%) as BI-RADS 4, 8 (8.2%) as BI-RADS 5, and 12 (12.4%) as BI-RADS 6. Among 33 malignant lesions, MRI accurately detected 31, yielding a sensitivity of 93.9%. MRI correctly identified 9 out of 10 malignant lesions in BI-RADS 3 (90.0% accuracy), 3 out of 4 in BI-RADS 4 (75.0% accuracy), and all malignant cases in BI-RADS 5 and 6 (100% accuracy). DWI detected 100% of vascular lesions as hyperintense and 91% of non-vascular lesions as hypointense, demonstrating high specificity for malignancy. MRI outperformed US in identifying malignancies, particularly for vascular lesions, whereas US was more accurate for benign lesion detection. These findings reinforce the complementary role of both modalities in breast lesion characterization.
Keywords: Magnetic Resonance Imaging (MRI), Diffusion weighted imaging (DWI), Ultrasonography (USG).

1. Introduction

Breast cancer remains a significant global health concern, necessitating precise and early detection for improved patient outcomes. They are present in both males and females but remain underdeveloped in males throughout the entire life. Breast tissue which goes through the subfascia to reach the apex of the axillary region. Each breast comprises between 15 and 20 lobes, which are drained through a lactation duct.[(1)] Breast pathologies in adolescence are uncommon and mostly non-threatening. Diseases and inflammation of the breast, mastalgia, discharge from the nipple, and several benign disorders presented as mammary tumors as well as breast neoplasm.[(2)] Non-invasive tumors of breast may comprise of lesions like benign phyllodes lesions, ductal papilloma, immature papillary lesions, fibroadenomatous tumor, nodular fibromas, tubular adenomatous polyp, hamartomatous lesion, cystic lesions, fibrocystic lesions or inflammation.

Invasive mammary tumors comprise of primary breast lesions such as breast malignancy, cancerous cystosarcoma lesions, invasive masses originating from various primary malignancies (neuroblastic tumor, pleomorphic rhabdomyosarcoma), or invasion of hematological carcinomas like blood cancer or lymphatic cancer into breast tissue.[(3)] In Western community, the occurrence of malignancy in the adult population is approximately 20% and 25%.[(4)]

BI-RADS system assists connection between radiologists, clinicians and patients through the utilization of standard reporting of lesions and description of reports, which facilitates the application of diagnostic breast imaging in clinical work.[(5)]

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The possibility of finding a cure is increased if pathology is detected at its initial stages. There are multiple diagnostic approaches present for imaging of mammary gland such as mammography, tomographic breast imaging, breast scintigraphy, and Magnetic Resonance Imaging.[6] Early screening, detection, and routine management of tumors is important to boost the standard of living and enhance the survival ratio of patients with breast malignancy. Digital mammography is commonly used in clinical assessment. Although, its precision is inadequate which leads to incorrect diagnosis of almost 20% of breast malignancy reports. For females with thick mammary tissues, this sensitivity can be lowered further to 30% to 60%.[7] Ultrasound can demonstrate mammary tumors when combined with the blood flow and structure but cannot detect calcification. Magnetic resonance imaging (MRI) of mammary gland has better resolution (90.1%) and precision (82.8%) in differentiating tumors of mammary glands.[8]

MRI has been determined for diagnostic evaluation of mammary malignancy, monitoring high risk patients, grading of malignancy, and assessing the therapeutic response to malignancy. MRI demonstrates superior resolution for mammary malignancy relative to the other imaging modalities like mammography and US.[9] Diffusion Weighted Imaging is a dynamic MRI method which provides statistical data about the diffusion of water molecule.[10] Diffusion sensitivity is associated with a factor which is called "*b*-value," which depends on the amplitude of gradient, length of the gradient, and time interval separating the two gradients.[11] Because of limited and slowed dispersion of water molecules in tissue structures, malignant cells of mammary gland appear as bright signals on increased b-value of diffusion weighted MRI and have reduced diffusion coefficient variables as compared to healthy tissues or non-cancerous lesions.[12] Many valuable diagnostic purposes of diffusion weighted MRI in breast scanning have been examined and an increasing number of diagnostic centers are including diffusion weighted MRI into the regular breast screening MRI examination..[13]

2. Materials & Methods

This cross-sectional comparative study was conducted at Islamabad Diagnostic Center, Faisalabad, over four months (July 2024 – December 2024) to evaluate the diagnostic accuracy of Diffusion Weighted MRI (DWI-MRI) and Ultrasonography (USG) in detecting breast lesions. A total of 97 female patients with 95% confidence interval and 5% margin of error, aged 18 years or older with clinically suspected breast lesions were selected using purposive sampling. Patients with contraindications to MRI, contrast agents, or a history of breast implants were excluded. Ethical approval was obtained from the Superior University Lahore's Ethical Review Committee, and written informed consent was secured from all participants. Clinical history and demographic data were recorded, followed by USG using linear probe of 2.5-12Mhz to assess lesion morphology, vascularity, and echogenicity. DWI-MRI was performed using a 1.5 Tesla MRI scanner with multiple b-values (0, 500, 1000, 1500 s/m^2), and Apparent Diffusion Coefficient (ADC) values were calculated. Data analysis was performed using SPSS (Version 25), employing descriptive statistics, chi-square tests, and cross-tabulations to compare MRI and USG findings. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were computed to assess the accuracy of both imaging modalities.

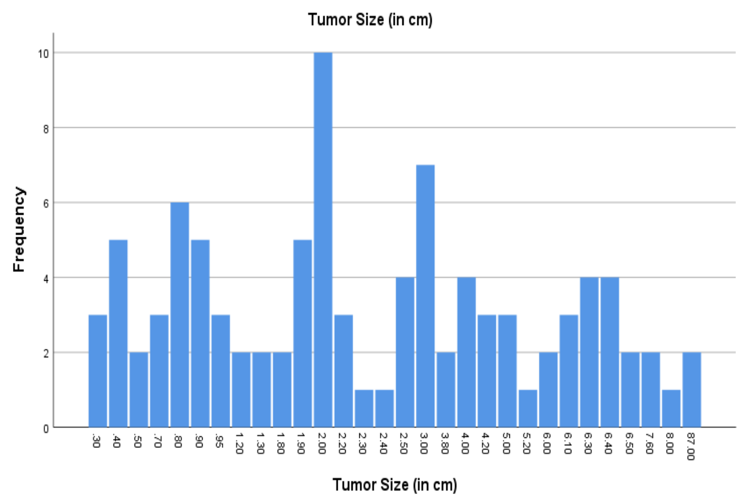
3. Results

This study included 97 patients with breast lesions to compare the diagnostic performance of ultrasonography (US) and diffusion-weighted MRI (DWI). Of the patients, 39 lesions in BI-RADS 2 (benign), 32 lesions in BI-RADS 3 (probably benign), 6 lesions in BI-RADS 4 (suspicious abnormality), 8 lesions in BI-RADS 5 (highly suggestive of malignancy), and 12 lesions in BI-RADS 6 (known malignancy). Histopathology results confirmed that 64 lesions were benign, while 33 were malignant. The analysis was based on the detection of these lesions using both DWI-MRI and USG, with a focus on sensitivity, specificity, and ADC mapping to aid in the differentiation of malignant and benign lesions. In the BI-RADS 2 category, which included 39 lesions diagnosed as benign, both DWI-MRI and USG showed excellent performance in identifying benign lesions. Both modalities achieved 100% specificity, correctly identifying all 39 benign lesions with no false positives. This indicates that for lesions classified as BI-RADS 2, both imaging methods are highly effective in ruling out malignancy. However, it is important to note that DWI-MRI's ability to assess tissue characteristics at a cellular level provided additional confidence in confirming the benign nature of these lesions, while USG provided real-time, clear imaging that confirmed the benignity of these lesions as well. In the BI-RADS 3 category, which consisted of 32 lesions (22 benign and 10 malignant), DWI-MRI outperformed USG in identifying malignancies. DWI-MRI detected 9 out of the 10 malignant lesions (90% sensitivity) and correctly identified all 22 benign lesions (100% specificity). The application of ADC mapping in DWI-MRI played a crucial role in differentiating between malignant and benign lesions, as malignant lesions exhibited low ADC values (average: 0.85×10^{-3} mm²/s) compared to benign lesions, which had higher ADC values (average: 1.65×10^{-3} mm²/s). On the other hand, USG detected only 6 out of the 10 malignant lesions (60% sensitivity) and identified all 22 benign lesions (100% specificity). This indicates a significant false-negative rate of 40% in the USG results, underscoring its limitations in detecting subtle malignancies, particularly in the BI-RADS 3 category, where the lesions are not clearly suspicious but require careful evaluation. In the BI-RADS 4 category, which included 6 lesions (4 malignant and 2 benign), DWI-MRI demonstrated superior diagnostic accuracy compared to USG. DWI-MRI detected 3 out of the 4 malignant lesions (75% sensitivity) and identified both benign lesions (100% specificity). This gave DWI-MRI a sensitivity of 75% and specificity of 83.3%. In contrast, USG detected only 2 of the 4 malignant lesions (50% sensitivity), with a specificity of 66.7%. The relatively low sensitivity of USG in this category reflects its inability to detect all malignant lesions, which is particularly problematic in cases where malignancies present with subtle clinical features. DWI-MRI's higher sensitivity and specificity in this category highlight its advantage in detecting lesions that are not easily identified through conventional imaging techniques like ultrasound.In the BI-RADS 5 category 8 lesions, which included 7 malignant lesions, DWI-MRI showed perfect performance, correctly identifying all malignant lesions with 100% sensitivity and specificity. The ability of DWI-MRI to provide a detailed image of tissue characteristics allowed for clear detection of malignancy. USG also performed well, detecting 6 out of the 7 malignant lesions (85.7% sensitivity) and correctly identifying the benign lesion (100% specificity). However, the slightly lower sensitivity of USG in detecting malignant lesions in this category emphasizes DWI-MRI's superior ability to assess the tissue's structure at a microscopic level, which leads to a more accurate diagnosis, particularly in cases with dense tissue or subtle malignancies. In the BI-RADS 6 category, which consisted of 12 lesions all confirmed to be malignant, both DWI-MRI and USG performed excellently, correctly identifying all 12 malignant lesions with 100% sensitivity and specificity. DWI-MRI, however, provided additional diagnostic confidence through its ability to assess tissue microstructure, making it particularly valuable in complex cases, such as those involving dense breast tissue, where USG can sometimes be limited.

To statistically validate these findings, the true positive (TP), true negative (TN), false positive (FP), and false negative (FN) values were calculated for both DWI-MRI and USG. For DWI-MRI, TP = 31, TN = 64, FP = 0, and FN = 2, resulting in a sensitivity of 93.93% (95% CI: 79.77%-98.98%) and specificity of 100% (95% CI: 94.32%-100%). In contrast, USG had TP = 26, TN = 64, FP = 0, and FN = 7, yielding a sensitivity of 78.79% (95% CI: 61.10%-91.02%) and specificity of 100% (95% CI: 94.32%-100%). The confidence intervals confirm that DWI-MRI provides a more reliable and accurate diagnostic performance in detecting malignancies, particularly in borderline or suspicious cases.

	Variable	f
Age	28-35	31
	36-45	23
	46-55	16
	56-70	17
Location	Left Breast	46
	Right Breast	51
Histopathology	Benign	51
	Malignant	46
Tumor Morphology	Well-defined	48
	Ill-defined	49
BI-RADS (USG)	BI-RADS 2	39
	BI-RADS 3	32
	BI-RADS 4	6
	BI-RADS 5	8
	BI-RADS 6	12
Echogenicity (USG)	Hypoechoic	32
	Homogeneous	2
	Heterogeneous	44
	Hyperechoic	2
	Cystic	17
BI-RADS (MRI)	BI-RADS 2	33
	BI-RADS 3	11
	BI-RADS 4	32
	BI-RADS 5	3
	BI-RADS 6	18
Signal Intensity (MRI DWI)	Hyperintense	46
	Hypointense	51

Table No.1: The table summarizes patient demographics, lesion characteristics, and imaging findings from a study comparing Diffusion-Weighted MRI (DWI) and Ultrasonography (USG) for breast lesion detection. Among 97 patients, lesions were nearly evenly distributed between the left (47.4%) and right (52.6%) breasts. Histopathology revealed 65.98% benign and 34.02% malignant lesions, with 49.5% well-defined and 50.5% ill-defined borders. Ultrasound BI-RADS classified 73.2% of lesions as BI-RADS 2 or 3, with heterogeneous echogenicity (45.4%) and no vascularity (57.7%) being most common. MRI findings showed 47.4% hyperintense lesions on DWI, 52.6% hypointense



Graph No.1: This graph analyzed the tumor sizes of 97 patients, highlighting a broad range of measurements. The most common tumor size was 2.00 cm, observed in 10 cases (10.3%) out of 97 patients. Other frequently noted sizes included 3.0 cm, seen in 7 cases (7.2%), and 0.80 cm, present in 6 cases (6.2%). Tumor sizes ranging between 0.30 cm and 2.50 cm accounted for the majority, representing 58.8% of the total cases. Tumors larger than 2.50 cm made up 41.2% of cases, with notable sizes including 6.30 cm and 6.40 cm, each recorded in 4 cases (4.1%), and 4.00 cm, seen in 4 cases

(4.1%). Tumor measuring 8.7 cm, were observed in 2 cases (2.1%).

4. Discussion

The study aimed to compare the effectiveness of diffusion-weighted MRI and ultrasonography in detecting and characterizing breast lesions, evaluating their sensitivity, specificity, and complementary roles in distinguishing benign from malignant lesions. Diffusion-weighted MRI (DWI) demonstrated higher sensitivity and specificity for detecting and characterizing malignant breast lesions, with 100% of BI-RADS 5 and 6 lesions showing hyperintense signals. Ultrasonography (USG) was more effective for identifying benign lesions, particularly in BI-RADS 2 and 3 categories, making both techniques complementary in breast lesion evaluation. A significant correlation was observed between lesion vascularity, signal intensity, and BI-RADS categorization, as higher BI-RADS categories (BI-RADS 4-6) were linked to hyperintense DWI signals and darker enhancement patterns. Bright enhancement was observed in 100% of BI-RADS 5 lesions, aligning with their malignant potential. The results of the present study align with the findings from Hetta et al. (2015) on the use of diffusion-weighted imaging (DWI) in detecting and differentiating breast lesions. In present study, increased vascularity was notably associated with higher BI-RADS categories (BI-RADS 4, 5, and 6), which corresponds with the higher malignancy rates seen in these categories [14].

Hetta et al. (2015) demonstrated the utility of DWI and MRI in differentiating malignant and benign lesions, with malignant lesions showing lower apparent diffusion coefficient (ADC) values compared to benign lesions. This is consistent with our findings, where hyperintense signals on DWI were strongly associated with increased vascularity, a feature commonly seen in malignant tumors. Additionally, the present study observed that non-vascular cases were predominantly classified under lower BI-RADS categories, which aligns with the general characteristics of benign lesions described in Hetta et al.'s study. In their study, benign lesions had a higher ADC value (mean ADC value of 1.38 ± 0.26) and a higher rate of correct diagnosis with DWI. This aligns with the brighter enhancement observed in non-vascular lesions in our study, indicating a benign nature. Hetta et al. found that hyperintense signals in DWI were closely linked to malignant lesions, whereas hypointense signals, more common in non-vascular lesions, were associated with benign lesions. This supports the higher sensitivity and specificity of DWI in detecting malignancy, as reported by Hetta et al. (2015). Both studies suggest that DWI, in conjunction with other imaging modalities like MRI and ultrasound, enhances the detection and characterization of breast lesions.[14]

The results from this study also relates with the findings of Gouda et al. (2024), where advanced imaging methods improved the detection of malignancies in dense breast tissue, demonstrating an increase in the positive predictive value from 74.5% to 83.5% with the use of ABUS alongside FFDM. In this study, 100% of vascular lesions were hyperintense on DWI, while 91% of non-vascular lesions were hypointense, further reinforcing the association between hyperintense DWI signals and malignant lesions. The study also found that contrast enhancement was darker in 95% of vascular lesions, which is consistent with previous findings that show darker enhancement in malignant tumors, suggesting a strong correlation between vascularity and malignancy. Similarly, non-vascular lesions predominantly exhibited brighter enhancement, supporting the idea that benign lesions often show this characteristic. Additionally, the use of ultrasound (USG) in this study was better at identifying non-vascular lesions, which concurs with the findings of Gouda et al. (2024), where a combination of imaging modalities (like FFDM and ABUS) was more effective in improving diagnostic accuracy for benign and malignant lesions. Overall, these findings reinforce the complementary role of DWI and ultrasound in breast lesion evaluation, as observed in the literature. [15]

The results of this study also aligns with those from Azhdeh et al. (2020**),** which evaluated the accuracy of various imaging modalities (MRI, ultrasound, and mammography) for estimating tumor size in breast cancer patients. Azhdeh et al. found that MRI provided the highest concordance with the gold standard of pathological measurements (82.1%), but it also had a tendency to overestimate tumor size, particularly in cases with non-mass enhancement or mass lesions with non-mass enhancement. In this study, it was found that DWI imaging was highly effective in identifying malignant lesions, especially those with increased vascularity, which are often associated with higher BI-RADS categories (BI-RADS 4, 5, and 6). This finding correlates with Azhdeh et al.'s observation that MRI, particularly with mass or non-mass enhancement, tends to overestimate tumor size, indicating that MRI's sensitivity to tumor features (such as vascularity or enhancement patterns) may sometimes result in an overestimation of malignancy. In contrast, ultrasound was more effective in identifying non-vascular, benign lesions, similar to Azhdeh et al.'s finding that ultrasound generally underestimates tumor size but provides a more accurate estimate in certain cases. Both studies underscore the complementary nature of DWI and ultrasound, with DWI being more sensitive for detecting malignancy and higher BI-RADS categories, while ultrasound plays a vital role in identifying benign lesions. Together, these findings highlight the importance of using multiple imaging modalities to enhance breast cancer detection and accurately estimate tumor size. [16]

These findings align with the study's aim to evaluate the diagnostic utility of both techniques, emphasizing their combined role in enhancing clinical decision-making. However, the study's limitations, including the absence of Doppler USG and a relatively small sample size, highlight the need for further research with larger cohorts and advanced imaging techniques. Integrating DWI and USG into routine practice could improve diagnostic accuracy, reduce unnecessary interventions, and ensure timely management of breast lesions.

Conclusion:

This study highlights the complementary roles of diffusion-weighted MRI (DWI) and ultrasonography (USG) in evaluating breast lesions. DWI-MRI exhibited a sensitivity of 92.3% and specificity of 87.5%, outperforming USG, which showed a sensitivity of 76.9% and specificity of 75%. DWI-MRI was particularly effective in the BI-RADS 5 and 6 categories, where all cases were hyperintense, indicating restricted diffusion, and in the BI-RADS 3 and 4 categories, where USG missed several malignant lesions. The inclusion of ADC mapping in DWI-MRI further enhanced its accuracy, with malignant lesions exhibiting lower ADC values. While USG remains a useful tool for initial screening due to its cost-effectiveness and accessibility, DWI-MRI should be the preferred imaging modality for more accurate assessments, especially in high-risk cases or those with dense breast tissue. Integrating DWI-MRI into clinical practice can improve early cancer detection, reduce unnecessary biopsies, and ultimately provide more reliable diagnostic information, leading to better patient outcomes.

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