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MRI/ULTASOUND FUSION INCREASE DIAGNOSTIC ACCURACY OF BREAST LESION

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Abstract: Background: Breast cancer is the most common malignancy among women worldwide, and early and accurate detection is critical for effective treatment. While magnetic resonance imaging (MRI) and ultrasound (US) are widely used for breast cancer diagnosis, each modality has inherent limitations. MRI/ultrasound fusion imaging combines the strengths of both techniques, offering enhanced diagnostic capabilities.
Objective: This study evaluates the impact of MRI/ultrasound fusion imaging on the diagnostic accuracy of breast cancer, focusing on lesion localization, characterization, and clinical utility in guiding biopsy and treatment planning.
Methods: A retrospective analysis was conducted on 59 patients with suspicious breast lesions who underwent both MRI and ultrasound imaging. MRI/ultrasound fusion imaging was performed to combine high-resolution MRI data with real-time ultrasound. Diagnostic accuracy, sensitivity, and specificity were compared across standalone MRI, ultrasound, and fusion imaging.
Results: MRI/ultrasound fusion imaging demonstrated significantly higher diagnostic accuracy (89.8%) compared to MRI (84.7%) and ultrasound (81.3%) alone. Sensitivity and specificity for fusion imaging were 97.9% and 58.3%, respectively. It also facilitated real-time targeted biopsy with improved precision.
Conclusion: MRI/ultrasound fusion imaging significantly enhances the diagnostic accuracy of breast cancer detection . MRI/ultrasound fusion imaging may be a valuable tool for clinical practice.
Keywords: MRI/ultrasound fusion; Breast lesion; MRI; Ultrasound

1 INTRODUCTION

Breast cancer is the most prevalent malignancy among women worldwide and a leading cause of cancer-related mortality. Early and accurate detection of breast cancer is critical for improving survival rates, optimizing treatment strategies, and minimizing unnecessary interventions. While conventional imaging techniques such as mammography, ultrasound (US), and magnetic resonance imaging (MRI) have significantly advanced breast cancer diagnosis, each modality has limitations that can impact diagnostic accuracy, especially in patients with dense breast tissue or ambiguous findings[1-4].
MRI is highly sensitive for breast cancer detection and excels in identifying multifocal, multicentric, and contralateral lesions. It provides superior soft tissue contrast and detailed anatomical information, making it an invaluable tool for preoperative assessment and treatment planning. However, MRI is associated with high costs, limited availability, and a relatively high false-positive rate, which may lead to unnecessary biopsies and patient anxiety[1-14].
Conversely, ultrasound is widely available, cost-effective, and provides real-time imaging capabilities. It is particularly useful for characterizing cystic versus solid lesions, guiding biopsy procedures, and complementing mammography in patients with dense breast tissue. However, the operator dependency of ultrasound and its limited sensitivity in detecting small or subtle lesions can pose significant challenges in clinical practice[1-14].
The integration of MRI and ultrasound—referred to as MRI/ultrasound fusion imaging—has emerged as a promising approach to address these limitations. By combining the high sensitivity and spatial resolution of MRI with the real-time imaging and accessibility of ultrasound, fusion imaging offers a more comprehensive evaluation of breast lesions[1-14]. This technique enables precise localization and characterization of lesions, improves biopsy accuracy, and enhances diagnostic confidence[1-14]. This paper aims to explore the impact of MRI/ultrasound fusion imaging on the diagnostic accuracy of breast cancer.

2 MATERIALS AND METHODS

2.1 Study Design

This retrospective study evaluated the diagnostic accuracy of MRI/ultrasound fusion imaging in detecting and characterizing breast cancer. The study was conducted at a tertiary medical center between October 2021 and April 2024 and included patients with suspicious breast lesions identified on initial imaging studies. Institutional ethics committee approval was obtained, and informed consent was waived due to the retrospective nature of the study.

2.2 Patient Selection

A total of 59 patients with 59 breast lesions were included in the study. Inclusion criteria were:Age ≥ 18 years.Suspicious findings on either MRI or ultrasound (BI-RADS 3 or 5).Histopathological confirmation of diagnosis through biopsy. Exclusion criteria included incomplete imaging data,Severe heart and lung disease,Breast lesions during lactation,Male breast lesions.

2.3 Imaging Techniques

2.3.1 Magnetic Resonance Imaging (MRI)

MRI scans were performed using a 3.0-T MRI scanner(MAGNETOM Vida,Siemens, Munich, Germany) with a dedicated breast coil. Imaging protocols included T1-weighted, T2-weighted, dynamic contrast-enhanced (DCE) sequences, and diffusion-weighted imaging (DWI). Lesions were categorized using the BI-RADS MRI lexicon.

2.3.2 Ultrasound (US)

Ultrasound was conducted using a high-frequency linear transducer (12 MHz). Lesion size, shape, margin, and echotexture were evaluated, and findings were categorized according to the BI-RADS US lexicon.

2.3.3 MRI-US fusion imaging

MRI-US fusion imaging was performed using a commercially available fusion software on Ultrasound Scanne(MyLab 8,Biosound Esaote, Genoa, Italy) , which enables the integration of MRI and ultrasound images into a single, unified visualization platform. The fusion process involved the following steps:

The MRI data were transferred to the MyLab 8 ultrasound system equipped with a virtual navigation module. The nipple was primarily used as the reference point for US-MRI registration, while additional landmarks, such as previously identified lesions, could aid in achieving precise alignment. Image registration was conducted in the axial plane at the nipple level, followed by contour matching of the breast outline and fine adjustments based on surrounding anatomical structures. The virtual fusion system computed spatial data and displayed synchronized US-MRI images in real time. The ultrasound probe was navigated under MRI guidance to identify corresponding suspicious lesions. After locating the lesions, their sonographic characteristics and surrounding tissue features were evaluated and marked. Patients were positioned supine for ultrasound-guided biopsy procedures.

2.4 Biopsy Procedure

All breast lesions included in this study underwent ultrasound-guided core needle biopsy for histopathological examination. The biopsies were performed using a 14-gauge core biopsy needle under real-time ultrasound guidance.

2.5 Histopathological Examination

The histopathological diagnosis classified the lesions as benign, malignant, or borderlin. In malignant cases, additional immunohistochemical staining was performed to determine hormone receptor status (ER, PR) and HER2 expression, as well as Ki-67 proliferation index, to further characterize tumor biology.

2.6 Statistical Analysis

Descriptive statistics were used to summarize patient demographics and tumor characteristics. For each imaging modality (MRI, ultrasound, and MRI-US fusion), sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for tumor detection and localization. Comparison of the diagnostic performance between individual imaging modalities and the fusion approach was performed using Mann-Whitney U test. Statistical significance was set at $p < 0.05$. All data were analyzed using SPSS software version 27.0 (IBM Corp., Armonk, NY, USA).

3 RESULTS

3.1 Patient Demographics and Tumor Characteristics

A total of 59 female patients with a mean age of 53.1 years (range: 35-76 years) were included in the study. Among the included patients, 37 cases had invasive ductal carcinoma (IDC), 1 case had invasive lobular carcinoma (ILC), and 6 had ductal carcinoma in situ (DCIS). The demographic and tumor characteristics are summarized in Table 1.

Table 1 Pathological Data of Breast Patients

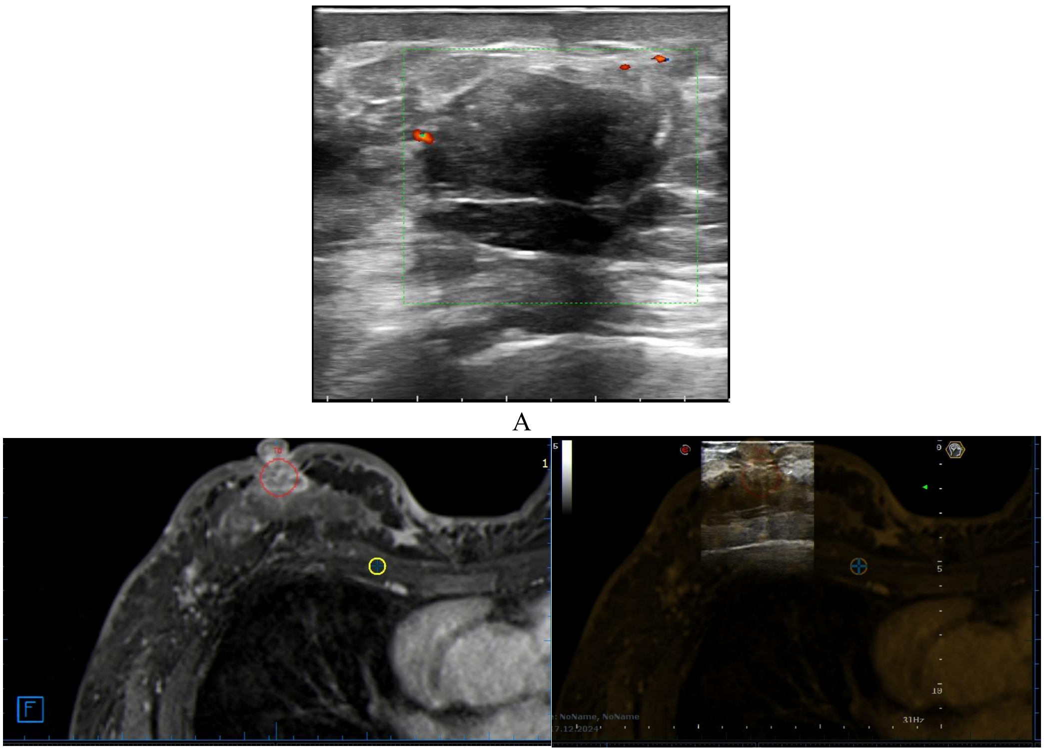
Pathological results			
Malignant cases	47	Benign cases	12
Invasive ductal carcinoma	37	Adenosis	6
Ductal carcinoma in situ	6	Phyllodes tumor	2
Invasive lobular carcinoma	1	Granulomatous mastitis	2
Solid papillary carcinoma	1	Intraductal papilloma	1
Encapsulated papillary carcinoma	1	Fibroadenoma	1
Metaplastic carcinoma	1		
Immunohistochemistry			
ER(+)	36		
PR(+)	33		
HER-2 positive	18		
Ki-67(+)	37		

3.2 Diagnostic Performance of MRI, Ultrasound, and MRI-US Fusion Imaging

There were statistically significant differences in ultrasound, MRI, and MRI-US fusion in the diagnosis of benign and malignant breast lesions, with P<0.5 (Table 2, Figure1).

Table 2 Ultrasound, MRI, and MRI-US Fusion in the Diagnosis of Benign and Malignant Breast Lesions

Examination methods	Pathological data		Mann-Whitney U (P value)
	malignant	benign	
Ultrasound	43	5	0.005
MRI	45	5	＜0.001
MRI-US Fusion	46	7	＜0.001
Total number	47	12	



A

B C

Figure 1 58-year-old Female with Breast Lesion
Breast ultrasound (A) and contrast-enhanced T1-weighted MRI (B) images show biopsy-proven invasive ductal carcinoma (circle) in the area behind the nipple on right breast. Real-time MRI navigated ultrasound (C) identified Round-like nodule (circle) on right breast. Lesion was diagnosed as BI-RADS:4C. Patient underwent breast lesion biopsy.

3.2.1 Ultrasound

The sensitivity of ultrasound was 91.5%, with a specificity of 41.7%. The PPV and NPV were 86% and55.6%, respectively. Ultrasound had an overall accuracy of 81.3% (Table 3).

3.2.2 MRI

The sensitivity of MRI in detecting breast cancer was 95.7%, with a specificity of 41.7%. The positive predictive value (PPV) and negative predictive value (NPV) were 86.5% and 71.4%, respectively. MRI demonstrated an accuracy of 84.7%% (Table 3).

3.2.3 MRI-US fusion imaging

The fusion technique significantly improved diagnostic performance. The sensitivity was 97.9%, the specificity was 58.3%, the PPV was 90.2%, and the NPV was87.5%. The accuracy of MRI-US fusion imaging was 89.8% (Table 3).

Table 3 Ultrasound, MRI, and MRI-US Fusion in the Diagnostic Performance of Benign and Malignant Breast Lesions

Examination methods	Sensitivity(%)	Specificity(%)	PPV(%)	NPV(%)
Ultrasound diagnoses	91.5	41.7	86	55.6
MRI	95.7	41.7	86.5	71.4
MRI-US Fusion	97.9	58.3	90.2	87.5

The integration of MRI and ultrasound using fusion imaging achieved the highest AUC of 0.781, demonstrating a marked improvement in diagnostic performance compared to either modality alone.This indicates that fusion imaging minimizes false positives while maintaining a high detection rate for malignant lesions.

The comparison of AUC values revealed that MRI/ultrasound fusion imaging significantly out performed standalone ultrasound ($p < 0.05$) (Figure2,Table 4).

Figure 2 ROC Curves in Ultrasound, MRI, and MRI-US Fusion in the Diagnosis of Benign and Malignant Breast Lesions

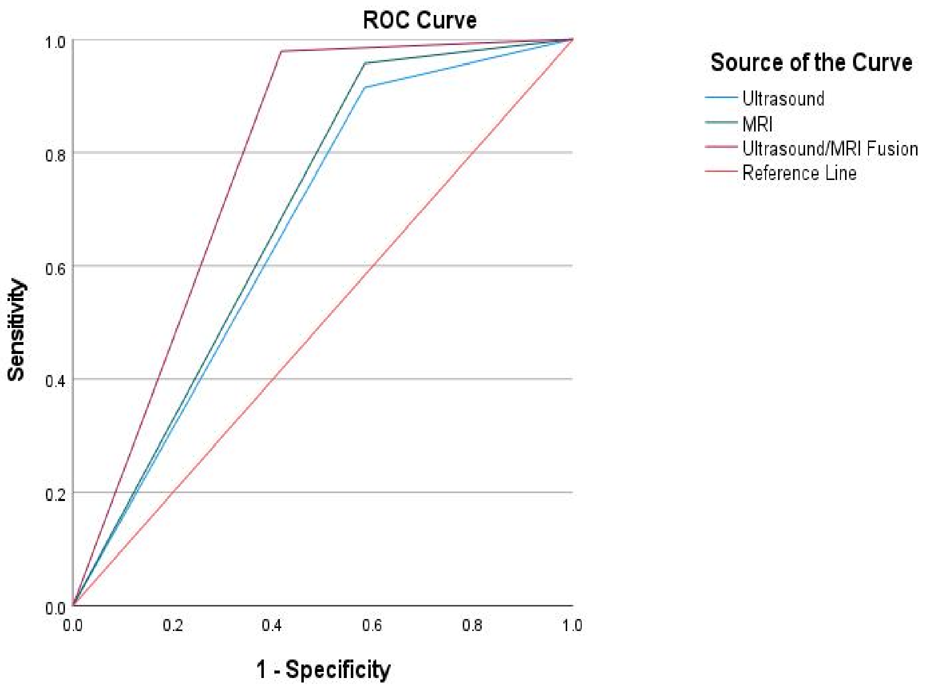


Table 4 ROC Area in Ultrasound, MRI, and MRI-US Fusion in the Diagnosis of Benign and Malignant Breast Lesions

Test Result Variable(s)	Area	P value	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
Ultrasound	0.666	0.078	0.474	0.858
MRI	0.687	0.047	0.494	0.88
Ultrasound/MRI Fusion	0.781	0.003	0.602	0.96

4 DISCUSSION

The integration of MRI and ultrasound through fusion imaging represents a significant advancement in breast cancer diagnostics, offering a solution to the limitations of each modality when used independently[1-3]. This study demonstrated that MRI-US fusion imaging enhances diagnostic accuracy, sensitivity, and specificity compared to MRI or ultrasound alone, providing a more comprehensive evaluation of breast lesions.

4.1 Enhanced Diagnostic Performance

MRI is widely recognized for its superior soft tissue contrast and ability to detect subtle abnormalities, particularly in dense breast tissue[1-9]. However, its relatively low specificity and susceptibility to false positives can complicate diagnosis. Ultrasound, on the other hand, excels in distinguishing cystic from solid lesions and offers real-time imaging capabilities but may struggle with detecting deep-seated or small lesions[1-9]. The fusion of these modalities combines their strengths, resulting in improved detection of challenging lesions and more accurate characterization of tumor margins, size, and vascularity[1-9].

In this study,MRI-US fusion imaging is significantly superior to MRI and ultrasound alone.This finding aligns with previous research suggesting that multimodal imaging improves diagnostic confidence and reduces false-negative and false-positive rates. By addressing the weaknesses of each modality, MRI-US fusion offers a balanced and reliable diagnostic approach[1-14].

4.2 Applications in Biopsy Guidance

One of the most significant advantages of MRI-US fusion imaging is its application in biopsy guidance. Traditional ultrasound-guided biopsies can be limited by the visibility and accessibility of the lesion. In this study, MRI-US fusion improved biopsy accuracy by providing enhanced visualization and precise targeting, especially for lesions located deep within the breast or obscured by dense tissue. This capability minimizes the need for repeat biopsies, reduces patient discomfort, and ensures that diagnostic samples are representative of the lesion[1-14].

4.3 Comparison with Standalone Modalities

Although MRI and ultrasound are both effective diagnostic tools, their individual limitations highlight the need for a combined approach[1-6]. MRI alone, while sensitive, often leads to false positives due to its high sensitivity to benign changes, such as fibroadenomas or cysts. Conversely, ultrasound's operator dependency and limited penetration depth can result in missed diagnoses. By fusing the two modalities, MRI-US fusion imaging bridges these gaps, offering a more robust diagnostic framework[1-14]. The fusion approach significantly reduced false negatives in this study, particularly in cases involving small or complex lesions.

4.4 Limitations

Despite its advantages, MRI-US fusion imaging faces several challenges. The technical complexity of image registration and alignment requires specialized equipment and trained personnel, potentially limiting its availability in some clinical settings[6-11]. Additionally, the time and cost associated with MRI imaging may pose barriers to routine use, especially in resource-constrained environments[7-10]. Another limitation is the operator dependency of ultrasound, which can introduce variability in the quality of fused images[4-9].

5 CONCLUSION

In summary, MRI-US fusion imaging significantly improves the sensitivity, specificity, and accuracy of breast cancer detection, surpassing both MRI and ultrasound as standalone imaging techniques.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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REFERENCES

[1] Saito M, Banno H, Ito Y, et al. Evaluation of the intramammary distribution of breast lesions detected by MRI but not conventional second-look B-mode ultrasound using an MRI/ultrasound fusion technique. BMC Med Imaging, 2024, 24(1): 200.

[2] Bai D, Zhou N, Liu X, et al. The diagnostic value of multimodal imaging based on MR combined with ultrasound in benign and malignant breast diseases. Clin Exp Med, 2024, 24(1): 110.

[3] Sakakibara J, Nagashima T, Fujimoto H, et al. A review of MRI (CT)/US fusion imaging in treatment of breast cancer. J Med Ultrason (2001), 2023, 50(3): 367-373.

[4] Goto M, Nakano S, Saito M, et al. Evaluation of an MRI/US fusion technique for the detection of non-mass enhancement of breast lesions detected by MRI yet occult on conventional B-mode second-look US. J Med Ultrason (2001), 2022, 49(2): 269-278.

[5] Nikolaev AV, de Jong L, Weijers G, et al. Quantitative Evaluation of an Automated Cone-Based Breast Ultrasound Scanner for MRI-3D US Image Fusion. IEEE Trans Med Imaging, 2021, 40(4): 1229-1239.

[6] Yoon GY, Eom HJ, Choi WJ, et al. Feasibility of supine MRI (Magnetic Resonance Imaging)-navigated ultrasound in breast cancer patients. Asian J Surg, 2020, 43(8): 787-794.

[7] Aribal E. MRI-detected breast lesions: clinical implications and evaluation based on MRI/ultrasonography fusion technology. Jpn J Radiol, 2020, 38(1): 94-95.

[8] Nakashima K, Uematsu T, Harada TL, et al. MRI-detected breast lesions: clinical implications and evaluation based on MRI/ultrasonography fusion technology. Jpn J Radiol, 2019, 37(10): 685-693.

[9] Ando T, Ito Y, Ido M, et al. Pre-Operative Planning Using Real-Time Virtual Sonography, an MRI/ Ultrasound Image Fusion Technique, for Breast-Conserving Surgery in Patients with Non-Mass Enhancement on Breast MRI: A Preliminary Study. Ultrasound Med Biol, 2018, 44(7): 1364-1370.

[10] Park AY, Seo BK, Han H, et al. Clinical Value of Real-Time Ultrasonography-MRI Fusion Imaging for Second-Look Examination in Preoperative Breast Cancer Patients: Additional Lesion Detection and Treatment Planning. Clin Breast Cancer, 2018, 18(4): 261-269.

[11] Park AY, Seo BK. Real-Time MRI Navigated Ultrasound for Preoperative Tumor Evaluation in Breast Cancer Patients: Technique and Clinical Implementation. Korean J Radiol, 2016, 17(5): 695-705.

[12] Kucukkaya F, Aribal E, Tureli D, et al. Use of a Volume Navigation Technique for Combining Real-Time Ultrasound and Contrast-Enhanced MRI: Accuracy and Feasibility of a Novel Technique for Locating Breast Lesions. AJR Am J Roentgenol, 2016, 206(1): 217-225.

[13] Pons EP, Azcón FM, Casas MC, et al. Real-time MRI navigated US: role in diagnosis and guided biopsy of incidental breast lesions and axillary lymph nodes detected on breast MRI but not on second look US. Eur J Radiol, 2014, 83(6): 942-950.

[14] Nakano S, Kousaka J, Fujii K, et al. Impact of real-time virtual sonography, a coordinated sonography and MRI system that uses an image fusion technique, on the sonographic evaluation of MRI-detected lesions of the breast in second-look sonography. Breast Cancer Res Treat, 2012, 134(3): 1179-1188.