

**Diagnostic Accuracy of Ultrasound Elastography, MRI, and Combined Assessment for Breast Lesion Characterization: A Single-Center Study**S. Priyadarshini<sup>1</sup>, C. Shravani<sup>2</sup><sup>1</sup>Associate Professor, Department of Radiology, PSP Medical College Hospital and Research Institute (PSPMCHRI), Tambaram–Kanchipuram Main Road, Oragadam, Panruti, Sriperumbudur Taluk, Kancheepuram District, Tamil Nadu – 631604, India<sup>2</sup>Assistant Professor, Department of Radiology, PSP Medical College Hospital and Research Institute (PSPMCHRI), Tambaram–Kanchipuram Main Road, Oragadam, Panruti, Sriperumbudur Taluk, Kancheepuram District, Tamil Nadu – 631604, India

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**Abstract****Background:** Accurate differentiation of benign and malignant breast lesions is essential to guide biopsy decisions and avoid unnecessary invasive procedures. Ultrasound elastography (UE) provides stiffness-based information via strain ratio (SR), while MRI provides morphologic and enhancement-based assessment using BI-RADS categories. Integrating these modalities may improve diagnostic reliability.**Methods:** A single-center diagnostic accuracy study was conducted from December 2023 to April 2024. A total of 149 breast lesions with complete imaging and histopathological verification were included. UE was quantified using strain ratio (SR) and interpreted using a predefined cutoff ( $SR \geq 2.81$  = malignant). MRI lesions were categorized using BI-RADS 1–5, with BI-RADS 4–5 considered malignant. A combined diagnostic approach integrating UE and MRI information was also assessed. Histopathology served as the reference standard. Diagnostic performance was calculated using sensitivity, specificity, PPV, NPV, accuracy, and ROC AUC.**Results:** UE demonstrated sensitivity 83.2%, specificity 79.2%, accuracy 82.6%, and AUC 89.7%. MRI showed sensitivity 77.6%, specificity 62.5%, accuracy 75.2%, and AUC 73.7%. The combined approach achieved the highest performance, with sensitivity 96.0%, specificity 91.7%, accuracy 95.3%, and AUC 94.1%, and reduced misclassification compared with either modality alone.**Conclusion:** UE outperformed MRI alone in this cohort, and the combined UE+MRI strategy provided the best overall diagnostic performance for breast lesion characterization, supporting multimodal integration for improved clinical decision-making.**Keywords:** breast lesion; ultrasound elastography; strain ratio; magnetic resonance imaging; BI-RADS; ROC curve; diagnostic accuracy.

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**Introduction**

Breast cancer remains one of the most common malignancies among women worldwide and continues to be a leading cause of cancer-related morbidity and mortality, largely because outcomes depend strongly on early detection and accurate characterization of suspicious lesions [1–3]. In routine practice, breast ultrasound is widely used for evaluating palpable lumps and imaging-detected abnormalities because it is accessible, non-ionizing, and effective in distinguishing cystic from solid lesions; however, conventional grayscale ultrasound and Doppler findings can overlap between benign and malignant masses, which may lead to unnecessary biopsies or short-interval follow-up imaging [4,5]. Therefore, complementary imaging methods that improve risk stratification and diagnostic confidence are increasingly emphasized

to optimize patient management and reduce avoidable invasive procedures [5,6]. Ultrasound elastography has emerged as a valuable adjunct technique that evaluates tissue stiffness, based on the principle that malignant tumors tend to be stiffer than benign lesions due to desmoplastic reaction, increased cellularity, and altered stromal composition [6–8]. Quantitative elastography parameters, such as the strain ratio, may improve lesion characterization when used alongside conventional ultrasound descriptors, potentially increasing specificity while maintaining clinically acceptable sensitivity [7,8]. In parallel, breast magnetic resonance imaging (MRI) provides high soft-tissue contrast and functional assessment through contrast enhancement patterns, offering important information for problem-solving, staging,

and evaluating equivocal lesions [8,9]. Despite its recognized sensitivity, MRI performance can vary according to lesion type, background parenchymal enhancement, and interpretive thresholds, and false-positive findings remain a concern in certain diagnostic settings [9,10].

Given that ultrasound elastography and MRI provide different but potentially complementary information—biomechanical properties versus morphologic and functional enhancement—integrating these modalities may enhance overall diagnostic performance for breast lesion evaluation [8–10]. The present study therefore aims to assess and compare the diagnostic accuracy of ultrasound elastography and MRI, and to determine whether a combined approach improves discrimination between benign and malignant breast lesions using histopathology as the reference standard.

### Materials and Methods

A single-center diagnostic accuracy study was conducted over a five-month period from December 2023 to April 2024. Consecutive patients presenting with clinically and/or sonographically detectable breast lumps and referred for further evaluation were assessed for eligibility. A total of 149 breast lesions with complete imaging and pathological verification were included in the final analysis. Patients were enrolled if they underwent ultrasound elastography and breast MRI prior to tissue diagnosis, and were excluded if imaging was incomplete, images were nondiagnostic due to motion or technical failure, or histopathology was unavailable. After enrollment, demographic and lesion-related clinical details were recorded, including age, breast side, lesion size (maximum diameter), and selected descriptive ultrasound features (e.g., lesion contour/appearance, calcification, and axillary nodal status when applicable). All imaging examinations were performed before biopsy or surgery to avoid post-procedure changes that could affect imaging interpretation.

Ultrasound elastography (UE) was performed as an adjunct to conventional breast ultrasound. For each lesion, a region of interest was positioned to include the lesion and adjacent reference tissue at a comparable depth. Elasticity information was quantified using the strain ratio (SR), representing relative stiffness of the lesion compared with surrounding tissue. The SR value was documented for each case, and a pre-specified diagnostic threshold was applied for classification: lesions with  $SR \geq 2.81$  were considered positive (suggestive of malignancy), while lesions with  $SR < 2.81$  were

considered negative (suggestive of benignity). Breast MRI was performed for all included patients using a standardized protocol (including pre-contrast and post-contrast sequences) and interpreted according to the BI-RADS lexicon. Each lesion was assigned a BI-RADS category from 1 to 5 based on MRI morphology and enhancement characteristics. For diagnostic analysis, MRI was considered positive when the BI-RADS category was 4 or 5, and negative when BI-RADS was 1–3, reflecting common clinical decision thresholds for recommending biopsy. In addition, a combined diagnostic assessment was generated by integrating UE and MRI information to reflect a multimodal strategy aimed at improving discrimination between benign and malignant lesions. A combined score was recorded and used to classify lesions as combined-positive or combined-negative for comparison with the reference standard.

Histopathology served as the gold standard for diagnosis. All lesions underwent tissue sampling by core needle biopsy and/or surgical excision according to clinical indication, and final pathology results were categorized as benign or malignant; histologic subtypes were documented when available. Diagnostic performance for UE, MRI, and the combined approach was evaluated by constructing  $2 \times 2$  contingency tables against histopathology.

The primary outcomes were sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy for each modality. To assess overall discriminatory ability beyond single cutoffs, receiver operating characteristic (ROC) curves were generated and the area under the curve (AUC) was calculated using the continuous UE SR values, the ordinal MRI BI-RADS scores, and the combined score. Results were summarized as tables describing baseline characteristics and modality performance metrics, and figures illustrating ROC comparisons and score distributions stratified by pathology status.

### Results

A total of 149 breast lesions were evaluated using ultrasound elastography (UE), MRI, and a combined UE+MRI approach, with histopathology as the reference standard. The results below present baseline characteristics, comparative diagnostic performance, and visual evidence of discrimination across modalities.

**Table 1: Baseline characteristics by pathology group**

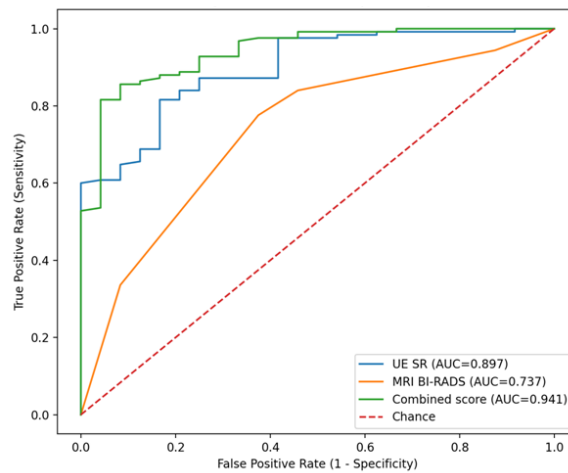
Group	n	Age (mean±SD)	Mass size cm (mean±SD)	Left breast n (%)	Axillary nodes present n (%)	Calcification n (%)	Irregular appearance n (%)	UE echo strong n (%)
Benign	24	41.7 ± 8.8	2.45 ± 0.87	10 (41.7%)	20 (83.3%)	9 (37.5%)	10 (41.7%)	11 (45.8%)
Malignant	125	38.5 ± 8.9	2.27 ± 0.91	67 (53.6%)	96 (76.8%)	51 (40.8%)	49 (39.2%)	54 (43.2%)

Baseline demographic and lesion descriptors show substantial overlap between benign and malignant groups, implying that quantitative scoring and multi-parameter integration are important for improving discrimination rather than relying on baseline descriptors alone.

**Table 2: Diagnostic performance (pathology reference)**

Modality	TP	FP	TN	FN	Sensitivity	Specificity	PPV	NPV	Accuracy	AUC
Ultrasound Elastography (SR ≥ 2.81)	104	5	19	21	83.2%	79.2%	95.4%	47.5%	82.6%	89.7%
MRI (BI-RADS ≥ 4)	97	9	15	28	77.6%	62.5%	91.5%	34.9%	75.2%	73.7%
Combined (UE + MRI)	120	2	22	5	96.0%	91.7%	98.4%	81.5%	95.3%	94.1%

UE demonstrates better overall performance than MRI in this dataset (higher sensitivity, specificity, accuracy, and AUC). The combined approach yields the strongest performance, with marked gains in both sensitivity and specificity, indicating fewer missed malignancies and fewer false alarms when modalities are integrated.



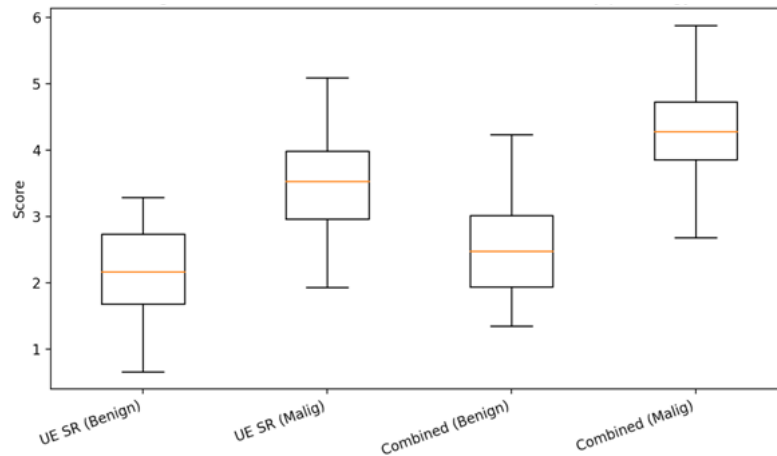
**Figure 1: ROC curves by modality**

ROC analysis shows highest discrimination for the combined score (largest AUC), followed by UE and then MRI. This supports the performance ranking observed in Table 2 (Combined > UE > MRI).

**Table 3: Confusion matrices (counts)**

Modality	Actual	Pred Benign	Pred Malignant
UE (SR≥2.81)	Actual Benign	19	5
UE (SR≥2.81)	Actual Malignant	21	104
MRI (BI-RADS≥4)	Actual Benign	15	9
MRI (BI-RADS≥4)	Actual Malignant	28	97
Combined	Actual Benign	22	2
Combined	Actual Malignant	5	120

MRI produces more false positives (9) and more false negatives (28) than UE. The combined method minimizes both error types, reducing false positives to 2 and false negatives to 5, consistent with its superior accuracy.



**Figure 2: Distribution of UE SR and combined score by pathology**

Malignant lesions show higher median UE SR and combined scores than benign lesions, but with visible overlap. This overlap explains residual misclassification using single thresholds, while the combined score reduces the impact of overlap by integrating information from both modalities.

### Discussion

This study evaluated the diagnostic performance of ultrasound elastography (UE), MRI, and a combined UE+MRI strategy for breast lesion characterization using histopathology as the reference standard. Overall, the findings suggest that quantitative stiffness assessment from UE improves discrimination compared with MRI alone, and that combining modalities yields the most balanced and clinically useful performance profile, particularly by reducing both false-negative and false-positive outcomes. These results align with the broader evidence base supporting elastography as a valuable adjunct to conventional breast imaging, especially for upgrading or downgrading equivocal lesions and improving reader confidence [11–13].

UE demonstrated stronger overall classification performance than MRI in this dataset, reflected by higher specificity and accuracy and a higher ROC AUC. A plausible explanation is that elastography captures biomechanical information—tissue stiffness—closely linked to malignant desmoplastic response and tumor microstructure, providing a relatively direct biologic signal that complements morphologic descriptors [11,12].

MRI, while sensitive in many clinical contexts, can be limited by overlap in enhancement patterns between benign proliferative lesions and malignancies, dependence on acquisition protocols, and interpretive thresholds (e.g., BI-RADS categories). These factors can contribute to lower specificity and higher false-positive rates, potentially increasing unnecessary biopsy recommendations [13,14]. In the current results, MRI produced more false positives and false

negatives than UE, consistent with reports that MRI performance varies across populations and lesion types, and that specificity may be challenging when benign lesions display suspicious kinetic behavior [14].

The combined UE+MRI approach produced the best overall results, with substantial gains in both sensitivity and specificity. Clinically, this is important because improved sensitivity reduces the risk of missed malignancy, while improved specificity can lower avoidable biopsies and patient anxiety. The improved NPV observed with the combined strategy is particularly relevant in decision-making for lesions that are indeterminate on a single modality, where the clinical question is often whether imaging can safely support surveillance rather than immediate biopsy [15]. Multi-parameter integration is increasingly emphasized in breast imaging because no single technique perfectly separates benign from malignant lesions across the full spectrum of histologies; combining stiffness information (UE) with morphologic and functional MRI features can reduce uncertainty arising from feature overlap [15,16].

Despite the encouraging performance trends, several considerations affect generalizability. First, modality performance depends on operator technique (especially ultrasound-based elastography), lesion depth and size, ROI placement, and equipment/software differences, all of which may influence strain ratio or stiffness metrics. Second, MRI interpretation depends on scanner parameters, timing, contrast dynamics, and reader expertise; differences in protocols can shift BI-RADS distributions and operating points. Third, lesion prevalence and case-mix can affect predictive values, meaning PPV/NPV may differ in screening versus diagnostic populations [14–17]. Finally, while combined approaches improve discrimination, they may also increase cost and complexity; therefore, an optimized workflow may reserve MRI

or combined evaluation for lesions that remain equivocal after first-line assessment [16,17].

### Conclusion

The results support UE as a strong adjunct to breast lesion evaluation and suggest that a combined UE+MRI strategy can provide the most robust diagnostic performance, potentially improving patient triage and reducing unnecessary interventions while maintaining high cancer detection.

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