

## Research Article

# MULTI-PARAMETRIC HIGH-RESOLUTION ULTRASONOGRAPHY IN EVALUATING SUPERFICIAL SOFT TISSUE SWELLINGS

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**Abstract:** **Introduction:** Superficial soft tissue swellings include a wide spectrum from benign to malignant lesions. High-resolution ultrasonography (HRUS), especially with grayscale, Doppler, and strain elastography (multiparametric approach), improves diagnostic accuracy due to its availability, real-time imaging, and cost-effectiveness. **Objective:** To assess the diagnostic accuracy of multiparametric HRUS in differentiating benign and malignant superficial soft tissue swellings using histopathology as the reference standard. **Materials and Methods:** This prospective study included 32 patients with superficial soft tissue swellings over six months (July 2025-January 2026). All lesions were evaluated using grayscale, Doppler, and strain elastography, and findings were correlated with histopathology. **Results:** Of 32 lesions, 18 were malignant and 14 benign on HRUS. Histopathological correlation showed concordance in 30 cases, yielding an accuracy of 94%, with two false-positive cases. **Conclusion:** Multiparametric HRUS is a reliable, non-invasive tool for differentiating superficial soft tissue swellings, with lesion morphology, vascularity, and stiffness significantly improving diagnostic accuracy.

**Keywords:** High-resolution ultrasonography, Doppler, strain elastography, soft tissue lesions, diagnostic accuracy)

## INTRODUCTION

Superficial soft tissue swellings are commonly encountered across all age groups and encompass a broad spectrum of conditions, ranging from inflammatory processes to benign and malignant neoplasms. Although the majority are benign, early and accurate differentiation from malignant lesions is crucial for optimal patient management and prognosis.

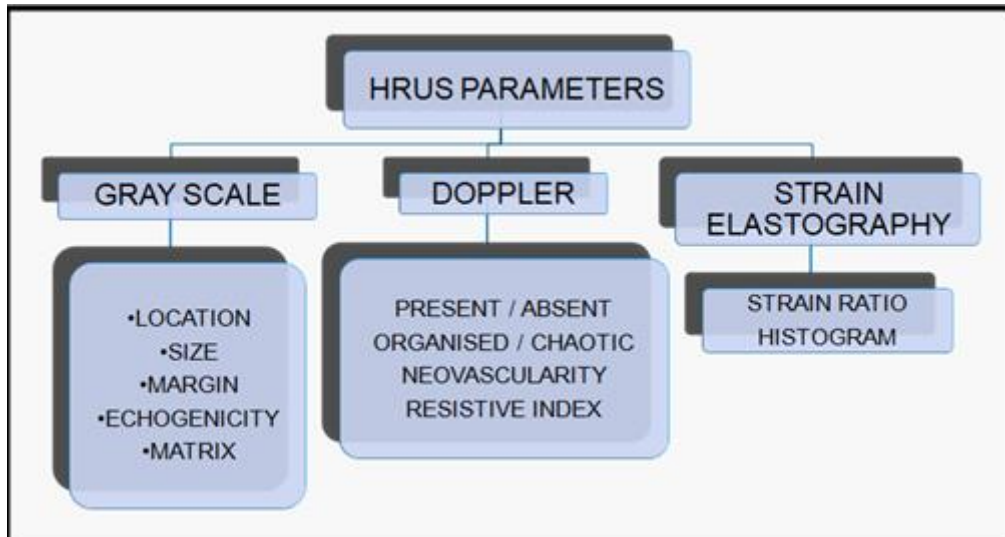
High-resolution ultrasonography (HRUS) has become the primary imaging modality for evaluating superficial soft tissue lesions owing to its excellent spatial resolution, real-time capability, wide availability, portability, and absence of ionizing radiation (1). Grayscale imaging provides valuable morphological information, including lesion size, margins, internal architecture, and echogenicity; however, significant overlap in imaging appearances between benign and malignant lesions often limits its diagnostic specificity when used alone.

Doppler imaging complements grayscale evaluation by assessing vascular patterns and hemodynamic characteristics, with malignant lesions frequently demonstrating increased internal vascularity and elevated resistive indices due to neoangiogenesis (2). Strain elastography further enhances diagnostic performance by evaluating tissue stiffness, which is typically higher in malignant lesions as a result of increased cellularity and fibrotic components (3).

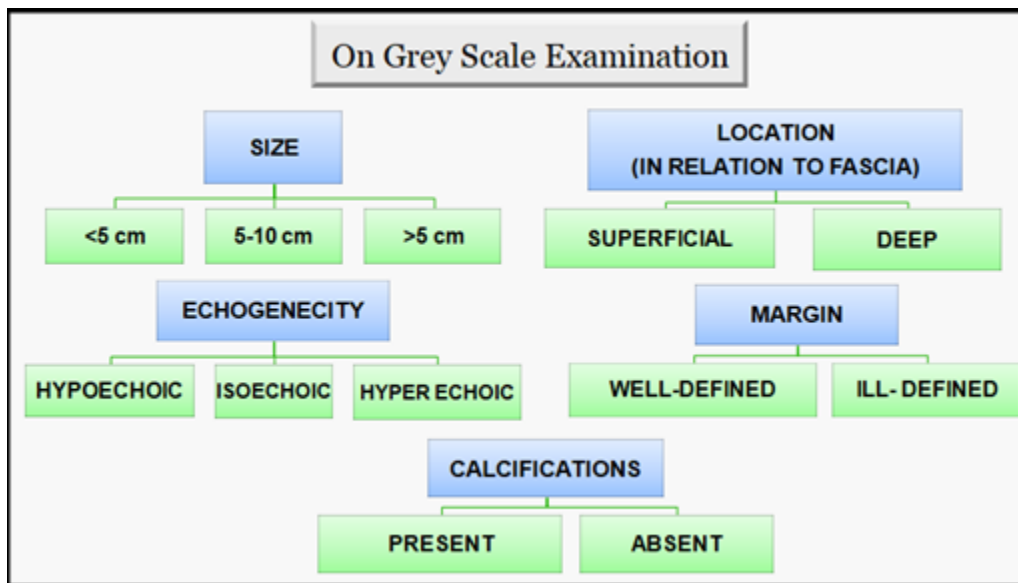
The integration of grayscale, Doppler, and elastography in a multiparametric approach significantly enhances diagnostic accuracy, improves lesion characterization, and reduces unnecessary invasive procedures (4). Despite these advancements, the imaging differentiation of soft tissue swellings can still be challenging, and histopathological examination remains the definitive standard for diagnosis in most cases.

## MATERIALS AND METHOD

This prospective observational study was conducted in the Department of Radiology & Imageology at ESIC Medical College & Hospital, Hyderabad, India, from July 2021 to January 2026. A total of 32 patients of all age groups presenting with clinically palpable superficial soft tissue swellings were included. Patients with purely cystic lesions such as abscesses and ganglion cysts, vascular malformations including arteriovenous and venous malformations, and lesions of the thyroid and breast were excluded. All ultrasound examinations were performed using a Samsung V7 system equipped with a high-frequency linear transducer (12–14 MHz). Each lesion was evaluated using multiparametric high-resolution ultrasonography (Figure 1), including grayscale imaging (Figure 2), Doppler assessment, and strain elastography, and findings were later correlated with histopathological examination wherever available.

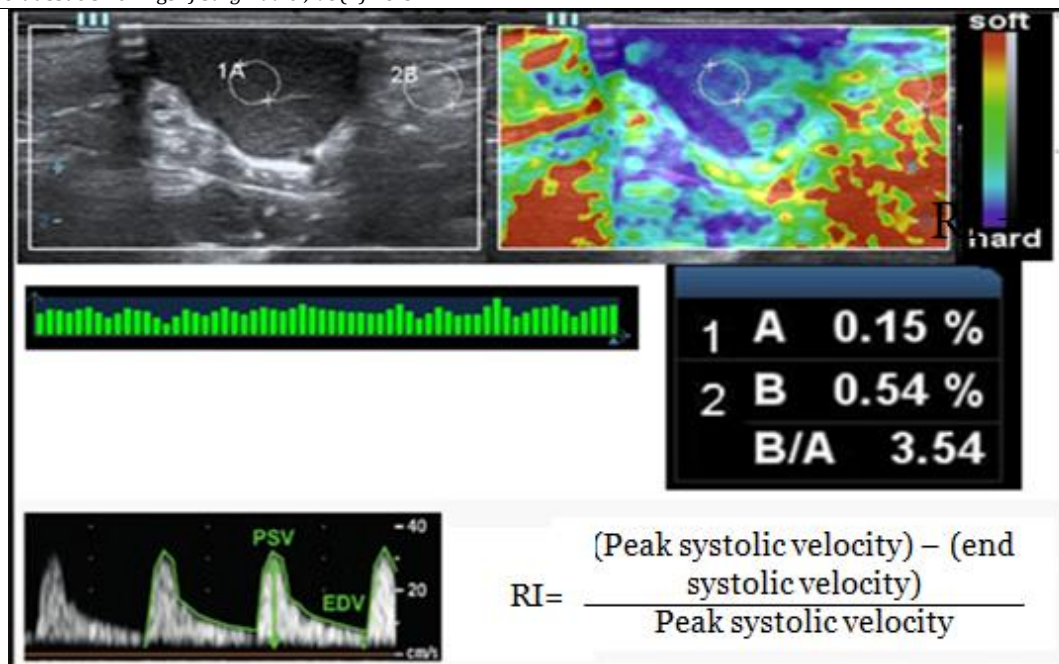


(Figure 1 : flow chart of HRUS parameters)



(Figure 2: flow chart of Grey scale examination)

On doppler examination, resistive index values are calculated using the formula (Figure 3). The strain ratio was determined by comparing the relative stiffness of the lesion to that of the surrounding normal tissue. Two regions of interest (ROIs) were selected: one placed within the lesion (A) and the other in adjacent normal soft tissue at the same depth (B). The ultrasound system automatically calculated the strain ratio as B/A, providing a semi-quantitative measure of tissue stiffness, with higher values indicating increased rigidity of the lesion.



(Figure 3: formula of Resistive Index calculation)

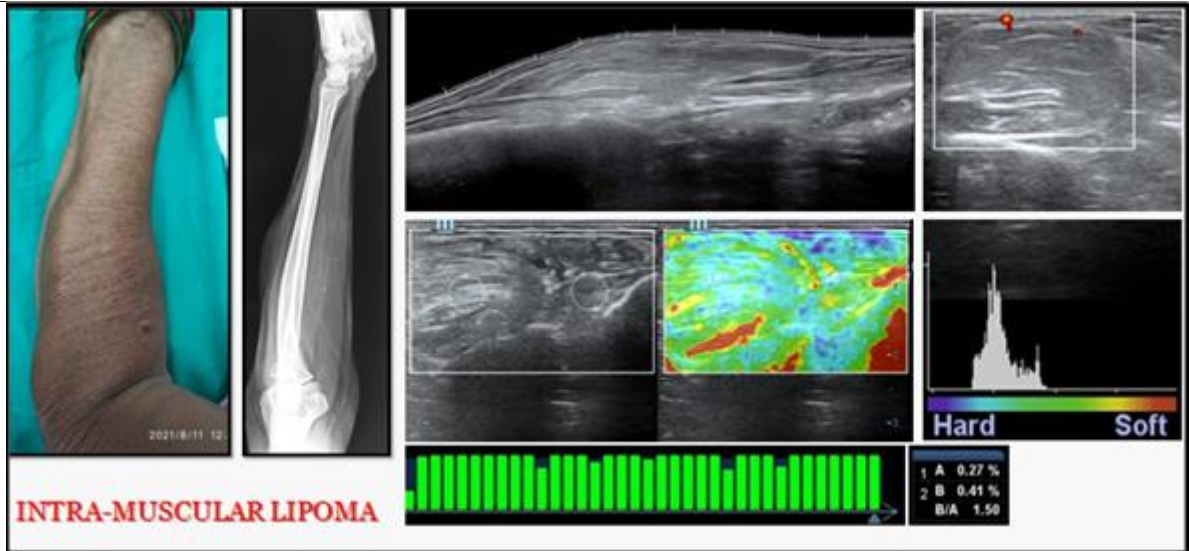
## RESULTS

Following HRUS evaluation, each soft tissue swelling was provisionally categorized as benign or malignant. All patients subsequently underwent biopsy or surgical excision, and final diagnosis was established by histopathological examination (HPE). Individual HRUS parameters—including grayscale features (size, echogenicity, margins, and location relative to fascia), vascularity patterns, resistive index, and strain elastography—were systematically compared between benign and malignant groups, and their statistical significance was analyzed.

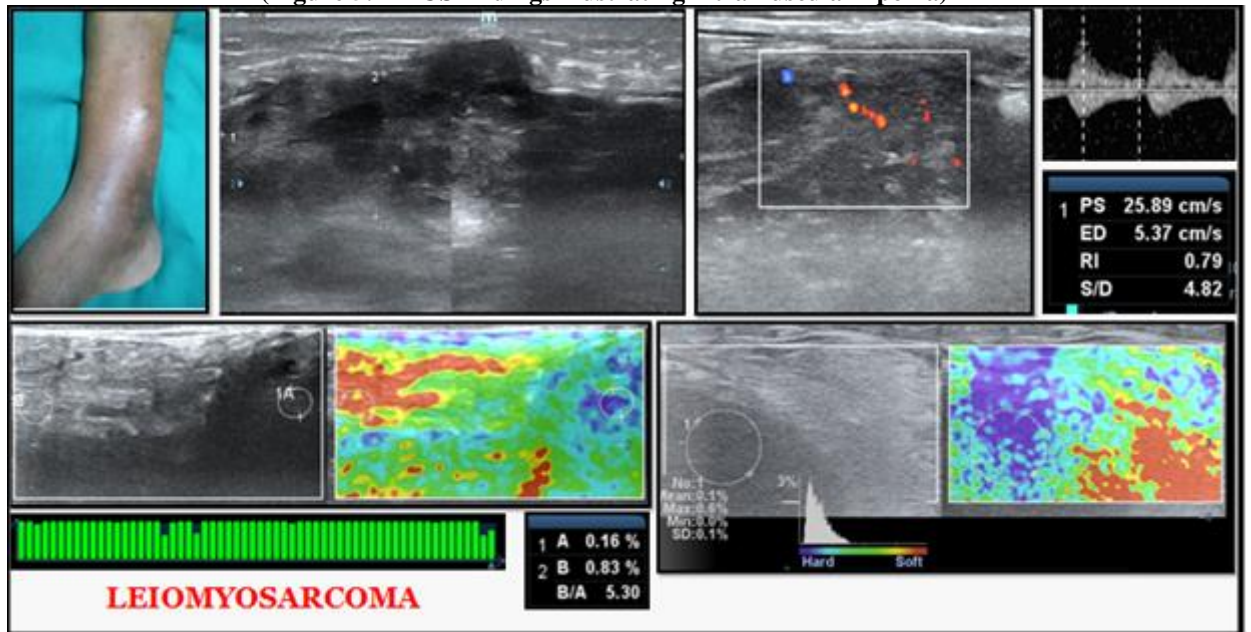
Lesion size showed a significant association with malignancy ( $p < 0.05$ ), with the majority of benign lesions measuring less than 5 cm, whereas malignant lesions were more frequently larger than 5 cm. Similarly, lesion location demonstrated statistical significance ( $p < 0.05$ ), as most malignant lesions were located deep to the fascia, while benign lesions were predominantly superficial. Echogenicity and margin characteristics did not show statistically significant differences ( $p > 0.05$ ), with most lesions in both groups appearing hypoechoic and a substantial proportion demonstrating well-defined margins. Vascularity patterns were significantly different between the two groups ( $p < 0.05$ ). Benign lesions commonly showed absent or organized vascularity, whereas malignant lesions predominantly exhibited chaotic vascular patterns suggestive of neovascularization. The presence of calcifications was also significantly associated with malignancy ( $p < 0.05$ ), although occasional benign lesions demonstrated calcifications. Strain elastography further contributed to differentiation, with malignant lesions showing higher stiffness compared to benign lesions. However, resistive index values did not demonstrate a statistically significant difference between the groups.

Overall, the combined use of multiparametric HRUS features provided a reliable distinction between benign and malignant soft tissue lesions, with several parameters—particularly size, location, vascularity, calcifications, and strain elastography—demonstrating significant diagnostic value.

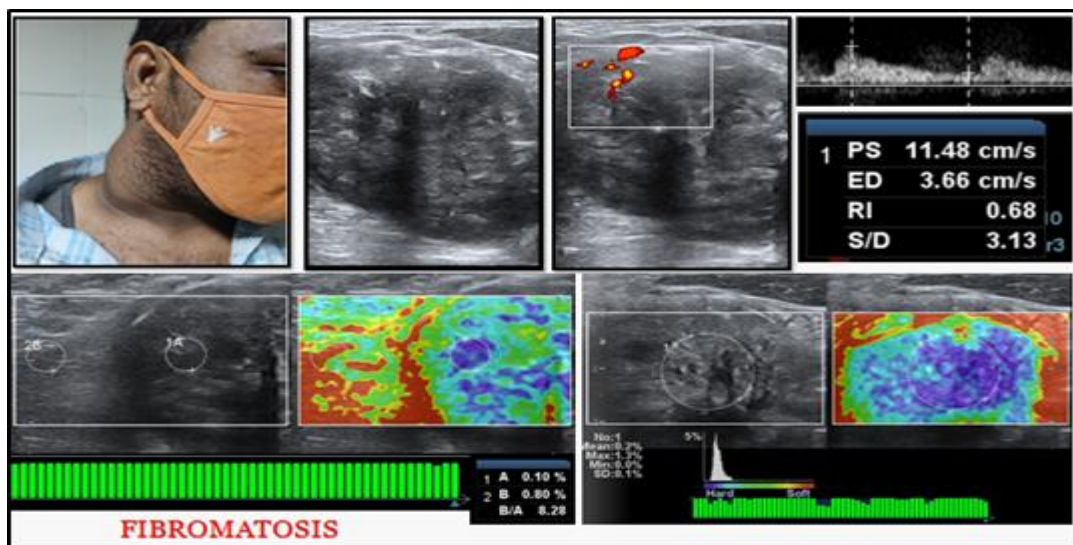
In the present study a total of 32 patients with soft tissue swellings were evaluated using high-resolution ultrasonography (HRUS). Of these, 18 lesions were provisionally classified as malignant and 14 as benign. Comparison with histopathological findings demonstrated a high level of diagnostic concordance, with 30 cases correctly identified, 2 false-positive results, and no false negatives, yielding an overall accuracy of 94%. On imaging, malignant lesions were more commonly characterized by larger size, irregular or poorly defined margins, heterogeneous echotexture, increased internal vascularity, and elevated strain ratios reflecting greater tissue stiffness. In contrast, benign lesions typically appeared well-circumscribed, with homogeneous echotexture, minimal or peripheral vascularity, and lower strain ratios. These findings are in line with existing literature, reinforcing the importance of vascular patterns and tissue stiffness as key indicators in distinguishing malignant from benign soft tissue lesions. A selection of representative case illustrations demonstrating the HRUS findings is presented in the following figures (Figure: 4,5,6,7).



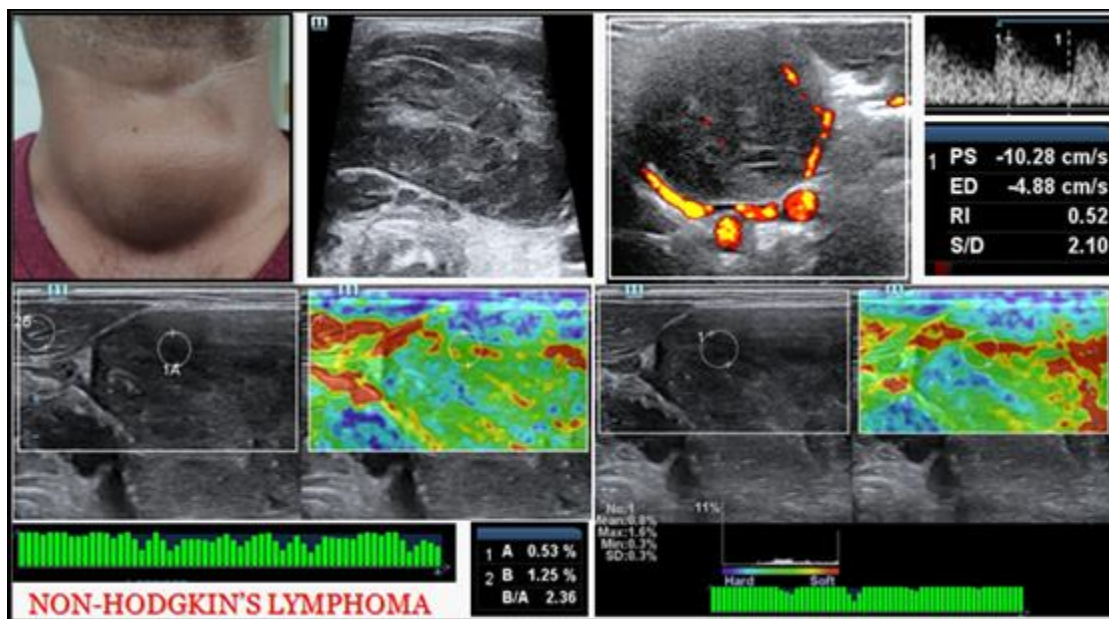
(Figure 5: HRUS findings illustrating intramuscular lipoma)



(Figure 5: HRUS findings illustrating leiomyosarcoma)



(Figure 5: HRUS findings illustrating Fibromatosis)



(Figure 6: HRUS findings illustrating Non Hodgkin's Lymphoma)

## DISCUSSION

The present study included 32 patients across a wide age range presenting with soft tissue swellings, of which 16 were benign and 16 malignant on final histopathological evaluation. The benign group comprised lipomas (n=4), fibromas (n=3), hemangiomas (n=2), epidermal inclusion cyst (n=1), lymphadenopathy (n=1), myxoma (n=1), and pilomatricoma (n=1). The malignant group included sarcomas (n=7), carcinomas (n=2), metastatic deposits (n=2), recurrent lesions (n=2), metastatic lymph nodes (n=2), and lymphoma (n=1). Lesion size emerged as a significant discriminator, with 80% of benign lesions measuring less than 5 cm, whereas 60% of malignant lesions exceeded 5 cm, consistent with previous observations. Lesion location relative to the fascia also showed statistical significance, as the majority (approximately 90%) of malignant lesions were located deep to the fascia (intermuscular or intramuscular), in agreement with earlier studies(4).

S.NO	FEATURE	p-value
01	SIZE	0.038*
02	LOCATION (IN RELATION TO FASCIA)	0.02*
03	ECHOGENICITY	0.072
04	MARGIN	>0.99
05	CALCIFICATIONS	0.026*
06	VASCULARITY	0.017*
07	RESISTIVE INDEX	0.613
08	STRAIN RATIO	<0.0001*

(Table 1: p-Value of multiple HRUS parametes)

In contrast, margin characteristics did not demonstrate diagnostic utility, as approximately 75% of both benign and malignant lesions were well defined, indicating no significant difference between the groups (5). Similarly,

echogenicity was not a reliable differentiating feature, with most benign (60%) and malignant (93%) lesions appearing hypoechoic (6). However, hyperechogenicity was predominantly associated with benignity, as the majority of hyperechoic lesions were benign. The presence of internal calcifications showed a meaningful association with malignancy, being observed in nearly half of malignant lesions, whereas only one benign lesion (pilomatricoma) demonstrated calcification, likely related to chronic changes.

Vascularity patterns provided important diagnostic insight. Approximately half of the benign lesions showed absent or minimal vascularity, while the remainder exhibited organized vascular patterns with regular branching. In contrast, the majority of malignant lesions (around 90%) demonstrated increased vascularity with chaotic, irregular branching patterns suggestive of neovascularization (7). Despite this (Table 1), resistive index values showed considerable overlap between benign and malignant groups and were not statistically significant (p = 0.613). Strain elastography (Table 2) proved to be a valuable adjunct, with malignant lesions exhibiting significantly higher stiffness, reflected by a mean strain ratio of 6.2 compared to 2.2 in benign lesions. However, the specificity was relatively lower (88%), as certain benign entities such as fibromatosis, scar endometriosis, and pilomatricoma also demonstrated increased stiffness. Overall, these findings highlight the importance of a combined multiparametric approach in improving diagnostic accuracy.

	MEAN STRAIN RATIO	RANGE
BENIGN	2.2	0.9 – 3.4
MALIGNANT	6.2	4.8 – 7.5

(Table 2: Mean strain ratio and range for benign and malignant groups were)

The findings of this study are in agreement with previous research highlighting lesion size, depth, vascularity, and stiffness as key indicators of malignancy. Earlier studies have also shown that echogenicity and margin characteristics have limited value as independent diagnostic predictors. The high diagnostic performance of strain elastography in the present study further supports its usefulness as a valuable adjunct to conventional ultrasound in differentiating benign and malignant soft tissue lesions (8). **Clinical Implications:** The integration of multiple HRUS parameters significantly improves diagnostic confidence in the evaluation of soft tissue swellings. This approach allows for better risk stratification and may reduce unnecessary invasive procedures in clearly benign cases, while facilitating early diagnosis and management of malignant lesions.

#### **Summary:**

Using a multiparametric high-resolution ultrasonography (HRUS) approach, 30 of 32 soft tissue swellings were accurately classified, achieving an overall accuracy of 94%. For benign lesions, HRUS showed a sensitivity of 88% and specificity of 100%, while for malignant lesions, sensitivity was 100% and specificity was 88%. The relatively lower specificity for malignancy is likely due to overlap in imaging features, as some benign lesions can mimic malignant characteristics such as hypoechogenicity, increased vascularity, and higher stiffness.

## **CONCLUSION**

Multiparametric high-resolution ultrasonography (grayscale, Doppler, and strain elastography) provides a reliable and accurate method for classifying soft tissue swellings into benign and malignant categories. Among the evaluated parameters, lesion size, depth (location relative to fascia), vascularity, and strain elastography were the most significant in distinguishing between the two groups, thereby enhancing diagnostic confidence and aiding clinical decision-making.

#### **Limitations:**

- Limited sample size
- Short duration of study
- Operator dependency of ultrasound techniques

#### **Future directions:**

- Larger, multicentric studies are recommended
- Standardization of elastography techniques and cutoff values
- Correlation with advanced imaging modalities such as MRI

**Conflict of interest:** Nil

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