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Original Research Article

Diagnostic Accuracy of High-Resolution Ultrasound with Doppler in Musculoskeletal Soft Tissue Lesions

Darshan Majmundar[1], Drumil Majmundar[2], Parin N. Shah[3]

[1]Department of Radio-diagnosis, SAL Institute of Medical Sciences, Ahmedabad, Gujarat, India.

[2]Assistant Professor, Department of Orthopaedics, SAL Institute of Medical Sciences, Ahmedabad, Gujarat, India

[3]Associate Professor Department of Biochemistry, SAL Institute of Medical Sciences, Ahmedabad, Gujarat, India

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Corresponding Author: Dr. Darshan Majmundar
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Abstract:

Background: Musculoskeletal soft tissue lesions encompass a broad spectrum of benign and malignant conditions that often present with overlapping clinical features. Early and accurate diagnosis is essential for appropriate treatment planning. High-Resolution Ultrasound (HRUS) with Color Doppler has emerged as a valuable, non-invasive imaging modality for evaluating these lesions because it provides excellent soft tissue resolution and real-time assessment of lesion vascularity.

Aim: To evaluate the diagnostic accuracy of High-Resolution Ultrasound with Color Doppler in the diagnosis and characterization of musculoskeletal soft tissue lesions using histopathology and/or magnetic resonance imaging (MRI) as the reference standard.

Materials and Methods: A prospective observational study was conducted in the Department of Radiodiagnosis of a SAL hospital over a period of 12 months. Fifty patients with clinically suspected musculoskeletal soft tissue lesions were enrolled consecutively. All patients underwent gray-scale HRUS followed by Color Doppler examination. Sonographic findings, including lesion size, margins, echogenicity, internal architecture, and vascularity, were recorded and correlated with histopathological examination and/or MRI findings. Diagnostic performance was assessed by calculating sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy.

Results: Among the 50 patients, the majority were aged 21–40 years (36%), with a slight male predominance (56%). The lower limb (42%) was the most common site of involvement. Most lesions demonstrated well-defined margins (72%) and hypoechoic echotexture (48%), while internal vascularity was observed in 38% of lesions on Color Doppler. Histopathological examination revealed that benign lesions accounted for 76% of cases, with lipoma (28%) being the most common diagnosis. Malignant lesions comprised 24% of cases. HRUS with Color Doppler demonstrated a sensitivity of 91.7%, specificity of 94.7%, positive predictive value of 84.6%, negative predictive value of 97.3%, and an overall diagnostic accuracy of 94.0%. HRUS findings showed excellent agreement with the reference standard, correctly diagnosing 47 of the 50 lesions.

Conclusion: High-Resolution Ultrasound with Color Doppler is a highly accurate, safe, and cost-effective imaging modality for the evaluation of musculoskeletal soft tissue lesions. It provides reliable differentiation between benign and malignant lesions and serves as an excellent first-line investigation. Correlation with histopathology and MRI confirms its diagnostic value, making HRUS with Color Doppler an effective tool for early diagnosis and treatment planning, particularly in resource-limited settings.

Keywords: High-Resolution Ultrasound; Color Doppler; Musculoskeletal Soft Tissue Lesions; Diagnostic Accuracy; Histopathology; Magnetic Resonance Imaging; Benign Soft Tissue Tumors; Soft Tissue Sarcoma; Ultrasonography; Musculoskeletal Imaging.

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Introduction

Musculoskeletal soft tissue lesions comprise a diverse group of pathological conditions arising from connective tissue, adipose tissue, skeletal muscle, peripheral nerves, blood vessels, synovium, bursae, and tendon sheaths. These lesions range from benign inflammatory and traumatic conditions to benign neoplasms and highly aggressive malignant soft tissue sarcomas. Although benign lesions account for the majority of musculoskeletal soft tissue masses encountered in clinical practice, distinguishing them from malignant lesions is essential because treatment strategies, prognosis, and long-term outcomes differ considerably. Early and accurate diagnosis facilitates appropriate management, minimizes unnecessary invasive procedures, and improves patient outcomes. [1,2] Patients with soft tissue lesions commonly present with swelling, localized pain, restricted joint movement, palpable masses, or a history of trauma. Clinical examination alone is often insufficient to characterize these lesions because of overlapping presentations and variable anatomical locations. Consequently, imaging plays a pivotal role in the initial evaluation, characterization, and management planning of musculoskeletal soft tissue abnormalities. [3]

Conventional imaging modalities include plain radiography, ultrasonography, computed tomography (CT), and magnetic resonance imaging (MRI). Plain radiographs are useful for detecting calcification, ossification, and bony involvement but have limited value in assessing soft tissue characteristics. MRI is widely regarded as the reference imaging modality because of its excellent soft tissue contrast and multiplanar capability. However, MRI is expensive, time-consuming, less accessible in resource-limited settings, and may be contraindicated in patients with implanted metallic devices, severe claustrophobia, or renal impairment requiring contrast administration. [4,5]

High-resolution ultrasonography (HRUS) has emerged as an important first-line imaging modality for evaluating superficial musculoskeletal soft tissue lesions. Advances in high-frequency linear transducers have enabled excellent visualization of superficial structures, allowing accurate assessment of lesion size, shape, margins, echogenicity, internal architecture, calcification, cystic changes, compressibility, and relationship to adjacent muscles, tendons, nerves, and vascular structures. HRUS offers several practical advantages, including wide availability, low cost, absence of ionizing radiation, portability, rapid image acquisition, and the ability to perform dynamic real-time examination. [6]

The addition of Color and Power Doppler imaging has substantially enhanced the diagnostic capability of ultrasonography. Doppler imaging provides valuable information regarding lesion vascularity, vascular distribution, flow velocity, and resistance indices. Benign lesions generally demonstrate absent or minimal internal vascularity, whereas malignant lesions often exhibit increased internal vascularity with irregular vascular architecture due to tumor angiogenesis. Although overlap exists between benign and malignant lesions, Doppler evaluation provides useful complementary information that improves diagnostic confidence and assists in selecting patients who require biopsy or advanced imaging. [7,8] High-resolution ultrasound is particularly useful for differentiating cystic from solid lesions, identifying abscesses, ganglion cysts, lipomas, vascular malformations, foreign bodies, tendon abnormalities, bursitis, muscle tears, hematomas, peripheral nerve tumors, and other superficial soft tissue masses. Furthermore, ultrasound enables real-time image-guided aspiration, biopsy, and therapeutic interventions with high precision and safety. These advantages have expanded its role in routine musculoskeletal practice and emergency settings. [9]

Despite these strengths, ultrasonography remains operator-dependent, and diagnostic accuracy may vary according to examiner experience, lesion depth, body habitus, and anatomical location. Deep-seated lesions and those adjacent to bone may be incompletely evaluated, often necessitating MRI for comprehensive assessment. Consequently, understanding the diagnostic performance of HRUS with Doppler in different clinical settings is important for defining its role in the diagnostic algorithm of musculoskeletal soft tissue lesions. [10] Several studies have reported high sensitivity and specificity of HRUS in the evaluation of superficial musculoskeletal lesions. Previous investigations have demonstrated diagnostic accuracies ranging from 80% to over 95% for differentiating cystic from solid lesions, identifying tendon and muscle injuries, and characterizing benign soft tissue masses. The incorporation of Doppler imaging further improves lesion characterization by assessing internal vascularity and assisting in distinguishing inflammatory, infectious, and neoplastic processes. Nevertheless, histopathological examination remains the definitive gold standard for diagnosing neoplastic lesions, while MRI continues to play an important complementary role for deep or indeterminate masses. [11-13]

In developing countries, where access to advanced imaging may be limited, HRUS with Doppler provides an economical and readily available alternative for the initial assessment of musculoskeletal soft tissue lesions. Establishing its diagnostic accuracy in comparison with histopathology and MRI may help optimize patient management, reduce unnecessary investigations, and improve cost-effective healthcare delivery.

Therefore, the present study was undertaken to evaluate the diagnostic accuracy of High-Resolution Ultrasound (HRUS) with Color Doppler in the diagnosis and characterization of musculoskeletal soft tissue lesions. The study also aimed to correlate the sonographic findings with histopathological and/or magnetic resonance imaging (MRI) findings, wherever available, to determine the sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy of HRUS with Doppler in the evaluation of musculoskeletal soft tissue lesions.

Materials and Methods

Study Design and Setting: A prospective observational diagnostic accuracy study was conducted in the Department of Radiodiagnosis at a SAL hospital over a period of 12 months. The study was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants before enrolment.

Study Population: Patients presenting with clinically suspected musculoskeletal soft tissue lesions and referred for ultrasonographic evaluation during the study period were included.

Inclusion Criteria

- Patients of all age groups and either sex with clinically suspected musculoskeletal soft tissue lesions.
- Patients willing to participate and provide written informed consent.
- Patients who subsequently underwent histopathological examination and/or MRI for confirmation of diagnosis.

Exclusion Criteria

- Patients with isolated bony lesions without soft tissue involvement.
- Patients with postoperative recurrent lesions without baseline imaging.
- Patients with inadequate imaging or incomplete clinical data.
- Patients unwilling to participate in the study.

Sample Size: A total of 50 patients with musculoskeletal soft tissue lesions were included in the study using consecutive sampling.

Ultrasound Examination: All patients underwent High-Resolution Ultrasound (HRUS) using a high-frequency linear transducer (7–15 MHz). Gray-scale ultrasonography was performed to assess lesion location, size, shape, margins, echogenicity, internal architecture, calcification, cystic changes, compressibility, and relationship to adjacent structures. Color and Power Doppler examinations were subsequently performed to evaluate lesion vascularity, vascular distribution, and flow characteristics. Lesions were categorized as benign or malignant based on predefined sonographic and Doppler criteria.

Reference Standard: The ultrasonographic diagnosis was compared with histopathological examination wherever tissue diagnosis was available. In lesions managed conservatively, MRI findings and clinical follow-up were considered the reference standard.

Data Collection: Demographic details, clinical presentation, lesion characteristics, ultrasonographic findings, Doppler vascularity, MRI findings, histopathological diagnosis, and final diagnosis were recorded using a structured proforma.

Outcome Measures: The primary outcome was the diagnostic accuracy of High-Resolution Ultrasound with Doppler in diagnosing musculoskeletal soft tissue lesions. Secondary outcomes included determination of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy of HRUS with Doppler.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were expressed as frequencies and percentages. Diagnostic performance was evaluated by calculating sensitivity, specificity, PPV, NPV, and overall diagnostic accuracy with 95% confidence intervals. The Chi-square test or Fisher's exact test was used to assess associations between categorical variables, and a p-value <0.05 was considered statistically significant.

Results

A total of 50 patients with clinically suspected musculoskeletal soft tissue lesions were included in the study. All patients underwent High-Resolution Ultrasound (HRUS) with Color Doppler examination, and the imaging findings were correlated with histopathological diagnosis and/or MRI findings.

Table 1: Age-wise Distribution of Patients

Age Group (Years)	Number	Percentage (%)
≤20	6	12.0
21–40	18	36.0
41–60	17	34.0
>60	9	18.0
Total	**50**	**100**

The majority of patients belonged to the 21–40 years age group (36.0%), followed by the 41–60 years age group (34.0%). The mean age of the study population was 41.8 ± 16.2 years, indicating that musculoskeletal soft tissue lesions were most frequently encountered among young and middle-aged adults.

Table 2: Gender Distribution

Gender	Number	Percentage (%)
Male	28	56.0
Female	22	44.0
Total	**50**	**100**

Among the study participants, 28 (56.0%) were males and 22 (44.0%) were females, showing a slight male predominance with a male-to-female ratio of approximately 1.3:1.

Table 3: Site of Musculoskeletal Soft Tissue Lesions

Site	Number	Percentage (%)
Upper limb	16	32.0
Lower limb	21	42.0
Trunk	8	16.0
Neck	5	10.0
Total	**50**	**100**

The lower limb (42.0%) was the most common site of involvement, followed by the upper limb (32.0%). Lesions involving the trunk and neck accounted for 16.0% and 10.0%, respectively.

Table 4: Sonographic Characteristics of Lesions

Sonographic Feature	Number	Percentage (%)
Well-defined margins	36	72.0
Ill-defined margins	14	28.0
Hypoechoic lesions	24	48.0
Mixed echogenicity	15	30.0
Hyperechoic lesions	11	22.0
Internal vascularity	19	38.0
No vascularity	31	62.0

Most lesions (72.0%) demonstrated well-defined margins on grayscale ultrasonography. Hypoechoic lesions were the most common echogenic pattern (48.0%), while internal vascularity on Color Doppler was identified in 38.0% of cases, suggesting increased vascular activity in selected lesions.

Table 5: Distribution of Final Diagnosis

Diagnosis	Number	Percentage (%)
Benign lesions	38	76.0
Malignant lesions	12	24.0
Total	**50**	**100**

Benign lesions constituted the majority (76.0%) of musculoskeletal soft tissue lesions, whereas malignant lesions accounted for 24.0% of the study population.

Table 6: Histopathological Diagnosis

Histopathological Diagnosis	Number	Percentage (%)
Lipoma	14	28.0
Ganglion cyst	8	16.0
Abscess	6	12.0
Hematoma	5	10.0
Peripheral nerve sheath tumour	5	10.0
Giant cell tumour of tendon sheath	4	8.0
Soft tissue sarcoma	8	16.0
Total	**50**	**100**

Lipoma (28.0%) was the most common histopathological diagnosis, followed by ganglion cysts (16.0%) and soft tissue sarcomas (16.0%). Other lesions included abscesses, hematomas, peripheral nerve sheath tumours, and giant cell tumours of the tendon sheath.

Table 7: Diagnostic Performance of High-Resolution Ultrasound with Doppler

Diagnostic Parameter	Value (%)
Sensitivity	91.7
Specificity	94.7
Positive Predictive Value	84.6
Negative Predictive Value	97.3
Diagnostic Accuracy	94.0

High-Resolution Ultrasound with Color Doppler demonstrated high sensitivity (91.7%) and specificity (94.7%) in differentiating benign from malignant musculoskeletal soft tissue lesions. The overall diagnostic accuracy was 94.0%, indicating excellent agreement with the reference standard.

Table 8: Correlation of HRUS Diagnosis with Reference Standard

HRUS Diagnosis	Confirmed	Not Confirmed	Total
Benign	36	2	38
Malignant	11	1	12
Total	**47**	**3**	**50**

HRUS with Color Doppler correctly diagnosed 47 of the 50 lesions, with only three cases showing disagreement with the reference standard. These findings demonstrate the reliability of HRUS with Doppler as an effective first-line imaging modality for evaluating musculoskeletal soft tissue lesions.

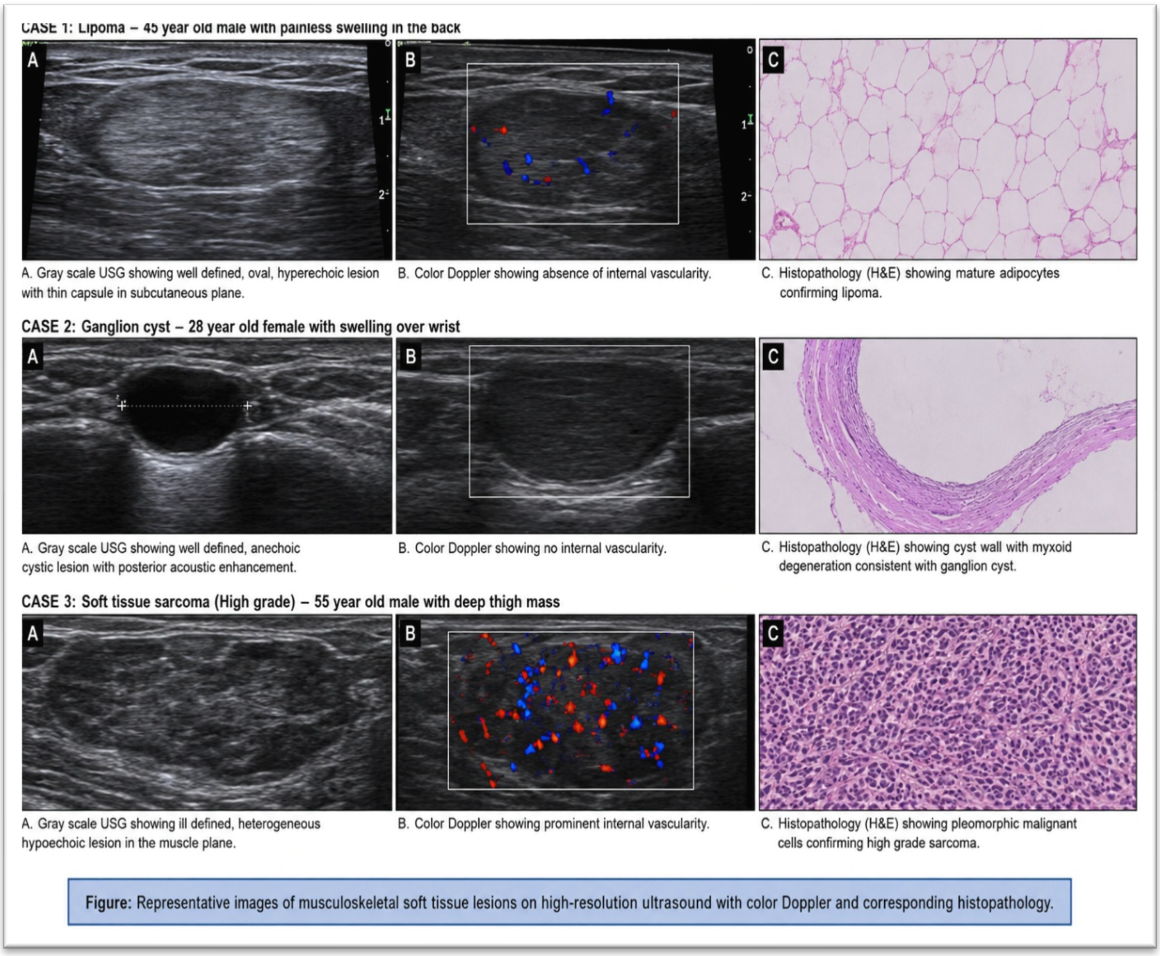

Figure 1:

Discussion

The present prospective observational study evaluated the diagnostic performance of High-Resolution Ultrasound (HRUS) with Color Doppler in the assessment of musculoskeletal soft tissue lesions. HRUS demonstrated excellent diagnostic performance with an overall diagnostic accuracy of 94.0%, sensitivity of 91.7%, specificity of 94.7%, positive predictive value of 84.6%, and negative predictive value of 97.3%. These findings support the role of HRUS with Doppler as a reliable first-line imaging modality for the evaluation of superficial musculoskeletal soft tissue lesions.

The majority of patients in the present study belonged to the 21–40 years age group, with a slight male predominance. Similar demographic findings have been reported by Kransdorf and Murphey, who observed that benign soft tissue tumors are more common in young and middle-aged adults, whereas malignant lesions occur relatively less frequently but require prompt diagnosis because of their aggressive behavior [14].

In the present study, the lower limb (42%) was the most common site of involvement, followed by the upper limb (32%). These findings are comparable with previous reports, where extremities were identified as the predominant location for musculoskeletal soft tissue masses due to the greater volume of soft tissue and higher exposure to trauma [15].

Gray-scale ultrasonography revealed that most lesions were well defined (72%) and predominantly hypoechoic (48%). Benign lesions generally demonstrated smooth margins, homogeneous echotexture, and absent or minimal vascularity, whereas malignant lesions showed irregular margins, heterogeneous echotexture, increased internal vascularity, and infiltration into adjacent tissues. Similar sonographic characteristics have been described by Bianchi and Martinoli, who emphasized that lesion morphology combined with Doppler evaluation significantly improves diagnostic confidence [16].

Color Doppler examination played an important role in lesion characterization by demonstrating internal vascularity in 38% of lesions. Increased vascularity was more frequently observed in malignant tumors and inflammatory lesions than in benign cystic lesions and lipomas. These findings are in agreement with the observations of Beggs, who reported that malignant soft tissue tumors commonly exhibit prominent internal vascularity because of neovascularization and tumor angiogenesis [17]. Histopathological examination showed that lipoma (28%) was the most common diagnosis, followed by ganglion cysts and soft tissue sarcomas. Similar distributions have been reported in previous studies, where lipoma represents the most common benign soft tissue tumor encountered in routine clinical practice [18]. Histopathology remains the gold standard for diagnosis; however, HRUS accurately characterized most lesions before tissue confirmation.

The overall diagnostic accuracy of 94% observed in the present study is consistent with previously published literature. Hung and Griffith reported that HRUS has diagnostic accuracies exceeding 90% for superficial soft tissue masses when combined with Doppler assessment [19]. Likewise, Chiou et al. demonstrated high sensitivity and specificity for differentiating benign and malignant lesions using high-resolution ultrasonography with Color Doppler [20].

The principal advantages of HRUS include real-time imaging, dynamic assessment, excellent spatial resolution for superficial structures, absence of ionizing radiation, portability, low cost, and the ability to perform image-guided aspiration or biopsy. These advantages make HRUS particularly valuable in resource-limited healthcare settings where MRI may not be readily available [21].

Nevertheless, the present study has certain limitations. The relatively small sample size and single-center design may limit the generalizability of the findings. Deep-seated lesions and lesions located adjacent to bone remain challenging to evaluate completely with ultrasonography and may require MRI for comprehensive assessment. Furthermore, the diagnostic accuracy of HRUS is operator dependent and influenced by the experience of the radiologist [22].

Overall, the findings of this study demonstrate that High-Resolution Ultrasound with Color Doppler is a highly accurate, safe, rapid, and cost-effective imaging technique for the initial evaluation.

Conclusion

High-Resolution Ultrasound (HRUS) with Color Doppler is a highly effective, non-invasive, and cost-efficient imaging modality for the evaluation of musculoskeletal soft tissue lesions. In the present study, HRUS with Doppler demonstrated excellent diagnostic performance, with high sensitivity, specificity, and overall diagnostic accuracy in differentiating benign from malignant lesions.

Gray-scale ultrasonography provided valuable information regarding lesion morphology, while Color Doppler improved lesion characterization by assessing vascularity, thereby increasing diagnostic confidence. The majority of lesions were benign, with lipoma being the most common histopathological diagnosis, whereas malignant lesions exhibited irregular margins, heterogeneous echotexture, and increased internal vascularity. Correlation with histopathology and/or MRI confirmed the reliability of HRUS with Doppler as an initial imaging investigation for musculoskeletal soft tissue masses.

The findings of this study suggest that HRUS with Color Doppler can serve as the first-line imaging modality in the diagnostic workup of musculoskeletal soft tissue lesions, particularly in resource-limited settings where MRI may not be readily available. Its advantages of real-time imaging, absence of ionizing radiation, portability, affordability, and capability for image-guided interventions make it an indispensable tool in routine clinical practice. However, deep-seated or indeterminate lesions should be further evaluated with MRI and histopathological examination for definitive diagnosis.

Overall, High-Resolution Ultrasound with Color Doppler provides accurate lesion characterization, facilitates early diagnosis and appropriate treatment planning, and has the potential to reduce unnecessary advanced imaging and invasive procedures, thereby improving patient care and clinical outcomes.

luation of musculoskeletal soft tissue lesions. It enables reliable differentiation between benign and malignant lesions, facilitates early diagnosis, and assists clinicians in selecting appropriate management while reducing unnecessary advanced imaging.

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