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Original Article

Role of Ultrasound, Color Doppler and Strain Elastography in Evaluation of Superficial Soft Tissue Lesions with Pathological Correlation

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ABSTRACT

Background: Superficial soft tissue lesions are diverse and may be challenging to characterize clinically. High-resolution ultrasound, color Doppler, and strain elastography offer non-invasive evaluation, aiding differentiation between benign and malignant lesions.
Objective: To assess the role of B-mode ultrasound, colour Doppler, and strain elastography in evaluating superficial soft tissue lesions and correlate findings with histopathology.
Materials and Methods: This prospective cross-sectional study included 69 patients with clinically suspected superficial soft tissue lesions referred for imaging between May 2023 and December 2024. All patients underwent B-mode ultrasound, colour Doppler, and real-time strain elastography. Lesion characteristics, vascularity, and strain ratios were recorded. Histopathological examination, when available, was used as the reference standard. Data were analysed using SPSS; $P < 0.05$ was considered significant.
Results: Benign lesions (n=52) were predominantly well-defined (65.4%), showed variable echogenicity, and had low or peripheral vascularity. Malignant lesions (n=17) were mainly ill-defined (88.2%), heterogeneous, and hypervascular, with higher resistivity and pulsatility indices. Strain elastography revealed significantly higher strain ratios in malignant lesions (mean SR higher than benign; $P < 0.001$). TES scores also differed markedly between benign and malignant lesions. Imaging findings showed a strong correlation with histopathology.
Conclusion: Multimodal ultrasound combining B-mode, colour Doppler, and strain elastography effectively differentiates benign from malignant superficial soft tissue lesions and correlates well with histopathology. This integrated approach provides a reliable, non-invasive tool for diagnosis and clinical management.

Keywords*: Superficial soft tissue lesions, Ultrasound, Colour Doppler, Strain elastography.*

INTRODUCTION

Superficial soft tissue lesions encompass a diverse group of pathologies, including benign tumours, malignant tumours, cystic lesions, vascular malformations, and inflammatory or infective conditions. Early and accurate diagnosis is crucial for appropriate management, as misdiagnosis may lead to delayed treatment, unnecessary interventions, or poor clinical outcomes [1,2].

Conventional clinical examination often has limited ability to accurately characterise these lesions due to overlapping physical features and variable lesion depth and consistency [3]. Imaging modalities, particularly ultrasound (USG), have

emerged as essential tools for evaluating superficial soft tissue lesions because of their non-invasive nature, real-time imaging capabilities, and high-resolution assessment of lesion morphology [4]. High-frequency linear probes allow detailed evaluation of lesion size, echogenicity, margins, internal architecture, and relation to adjacent structures [5].

Color Doppler imaging adds significant diagnostic value by providing information on vascularity patterns within the lesion. Malignant lesions typically exhibit increased vascularity with chaotic vessel distribution, whereas benign lesions usually show minimal or peripheral vascularity [6,7]. Parameters such as resistivity index (RI) and pulsatility index (PI) further aid in differentiating benign from malignant lesions [8].

More recently, strain elastography has been integrated with conventional ultrasound to assess tissue stiffness, which is an important characteristic of malignant transformation. Strain elastography measures the relative deformation of a lesion compared to adjacent normal tissue, expressed as a strain ratio (SR), with higher values generally indicating stiffer and potentially malignant tissue [9,10]. Several studies have demonstrated that combining B-mode ultrasound, color Doppler, and elastography improves diagnostic accuracy and helps guide clinical management decisions [11,12].

The present study was conducted to evaluate superficial soft tissue lesions using a multimodal ultrasound approach—B-mode USG, color Doppler, and strain elastography—and to correlate imaging findings with histopathology as the reference standard. This integrated approach aims to provide a non-invasive, accurate, and reproducible method for differentiating benign from malignant superficial soft tissue lesions.

MATERIALS AND METHODS

Study Design and Setting

A prospective cross-sectional study was conducted in the Department of Radiodiagnosis, Vydehi Institute of Medical Sciences and Research Centre, Bangalore, over the period of May 2023 to December 2024.

Study Population

The study population comprised patients clinically suspected of having superficial soft tissue lesions and referred for ultrasonographic evaluation.

Inclusion Criteria

- Patients presenting with clinical features suggestive of superficial soft tissue lesions.
- Patients willing to undergo ultrasound, colour Doppler, and elastography examinations.
- Patients providing written informed consent and willing to comply with follow-up when necessary.

Exclusion Criteria

- Post-operative patients.
- Patients with a prior confirmed histopathological diagnosis of the lesion.
- Patients refusing consent or unwilling to undergo imaging investigations.

Ethical Considerations

The study was initiated following approval from the Institutional Scientific and Ethical Committee. Detailed explanation of the procedure was provided in the patient's preferred language, and written informed consent was obtained from all participants.

Sample Size Calculation

The sample size calculation was based on the sensitivity of an integrated ultrasound approach reported by Abhiman Baloji et al., where sensitivity for detecting lesions such as epidermoid cysts was **80%**. The required sample size (n) was calculated using the formula:

$$n = \frac{Z_\alpha^2 \times Sn \times (100 - Sn)}{d^2}$$

Where:

- $Z_\alpha = 1.96$(for 95% confidence interval)
- $Sn = 80\%$
- $100 - Sn = 20\%$
- $d = 10\%$(absolute precision)

$$n = \frac{(1.96)^2 \times 80 \times 20}{10^2} = 61.46$$

Considering a 10% attrition rate, the final sample size was rounded to 69 patients.

Sampling Method
A consecutive sampling technique was used. All eligible patients referred to the department during the study period who met the inclusion criteria were enrolled until the target sample size was achieved.

Imaging Equipment
All examinations were performed using a PHILIPS AFFINITY 50G ultrasound machine equipped with a 5–12 MHz high-frequency linear array transducer.

This system supports B-mode ultrasound, colour Doppler, and real-time strain elastography.

Imaging Protocol
Ultrasound Examination
Patients were positioned comfortably depending on lesion site, and acoustic gel was applied to the transducer. Each lesion was systematically evaluated in axial and sagittal planes. The following parameters were assessed:

- Anatomical location
- Size and shape
- Margins and borders
- Echogenicity (hypoechoic, isoechoic, hyperechoic, heterogeneous)
- Internal architecture
- Presence of calcifications
- Surrounding tissue changes
- Vascularity using **colour Doppler** (graded as absent, minimal, moderate, or marked)

Elastography Examination
Real-time strain elastography was performed using the same transducer:

- The lesion was centred within the elastography window.
- Gentle rhythmic compression and decompression were applied, ensuring optimal compression index.
- A minimum of 5 mm of adjacent normal tissue was included for comparison.
- Two regions of interest (ROI) were placed—one over the lesion and one over adjacent normal soft tissue.
- The Strain Ratio (SR) was automatically calculated as:

$$SR = \frac{\text{Strain of reference tissue}}{\text{Strain of lesion}}$$

Higher strain ratios indicated greater lesion stiffness.

Pathological Correlation
Whenever clinically indicated or when surgical excision/biopsy was performed, histopathological findings were obtained and used as the reference standard for diagnostic correlation.

Outcome Measures

- Ultrasonographic characteristics of superficial soft tissue lesions
- Colour Doppler vascular patterns
- Elastography strain ratio values
- Imaging–histopathology diagnostic concordance

Data Management and Statistical Analysis
Data were entered and cleaned using Microsoft Excel before being analysed with IBM SPSS Statistics version 22 (Armonk, NY, USA).

- Categorical variables were summarised using frequencies and percentages.
- Continuous variables were expressed as mean ± standard deviation (SD).
- Associations between qualitative variables were evaluated using the Chi-square test or Fisher's exact test (for 2×2 tables).
- A P-value < 0.05 was considered statistically significant.
- Graphical representations (bar charts, pie charts, column diagrams) were generated using Microsoft Excel and Word.

RESULTS AND OBSERVATION

Table 1: Distribution of Subjects According to Age Group and Sex

Age Group (years)	Frequency	Percent	Female (n)	Male (n)
<20	11	15.9%	6	5
21–40	24	34.8%	15	9
41–60	24	34.8%	14	10
61–80	10	14.5%	6	4
Total	69	100%	41	28

Table 2: Association Between Histopathological Diagnosis and USG Findings (Concise)

Lesion Category	Histopathological Diagnosis (Representative)	Ill-defined (n, %)	Well-defined (n, %)
Benign Tumors	Lipoma, Neurofibroma, Intramuscular lipoma, Benign fibrous histiocytoma, Nodular fasciitis, Keloid	9 (27.3%)	13 (36.1%)
Malignant Tumors	Leiomyosarcoma, Liposarcoma, Malignant melanoma, Malignant peripheral nerve sheath tumor, Rhabdomyosarcoma, Squamous cell carcinoma, Synovial sarcoma	10 (30.3%)	1 (2.8%)
Cystic Lesions	Baker's cyst, Epidermoid cyst, Ganglion cyst, Sebaceous cyst, Cystic neurofibroma	0 (0.0%)	14 (38.9%)
Vascular Lesions	AVM, Hemangioma, Intramuscular hemangioma, Vascular malformation	2 (6.1%)	2 (5.6%)
Inflammatory/Infective	Abscess, Cellulitis, Foreign body granuloma, Post-injection swelling, Subacromial bursitis, Lateral malleolar bursitis, Infective granuloma	7 (21.2%)	0 (0.0%)

Table 3: Association of Histopathological Diagnosis with USG Findings and Benign Frequencies

Histopathological Diagnosis	Ill-defined (N, %)	Well-defined (N, %)	Benign (N)	Benign (%)
Abscess	1 (3.0%)	0 (0.0%)	1	1.9%
Achilles tendinosis	2 (6.1%)	0 (0.0%)	2	3.8%
AVM (vascular malformation)	1 (3.0%)	0 (0.0%)	1	1.9%
Baker's cyst	0 (0.0%)	4 (11.1%)	4	7.7%
Basal cell carcinoma	0 (0.0%)	1 (2.8%)	–	–
Benign fibrous histiocytoma	1 (3.0%)	0 (0.0%)	1	1.9%
Cellulitis	1 (3.0%)	0 (0.0%)	1	1.9%
Cutaneous metastasis	1 (3.0%)	0 (0.0%)	–	–
Cystic neurofibroma	1 (3.0%)	0 (0.0%)	–	–
Epidermoid cyst	0 (0.0%)	3 (8.3%)	3	5.8%
Foreign body granuloma	1 (3.0%)	0 (0.0%)	1	1.9%
Foreign body	1 (3.0%)	0 (0.0%)	1	1.9%
Ganglion cyst	0 (0.0%)	2 (5.6%)	2	3.8%
Haemangioma	0 (0.0%)	1 (2.8%)	1	1.9%
Hematoma	0 (0.0%)	1 (2.8%)	3	5.8%
Infective granuloma	0 (0.0%)	1 (2.8%)	1	1.9%
Intramuscular hemangioma	1 (3.0%)	0 (0.0%)	1	1.9%
Intramuscular lipoma	0 (0.0%)	1 (2.8%)	1	1.9%
Keloid	3 (9.1%)	1 (2.8%)	4	7.7%
Knee abscess	1 (3.0%)	0 (0.0%)	1	1.9%
Lateral malleolar bursitis	1 (3.0%)	0 (0.0%)	1	1.9%
Leiomyosarcoma	2 (6.1%)	0 (0.0%)	–	–
Lipoma	0 (0.0%)	11 (30.6%)	11	21.2%
Liposarcoma	2 (6.1%)	0 (0.0%)	–	–
Malignant melanoma	1 (3.0%)	1 (2.8%)	–	–
Malignant peripheral nerve sheath tumor	1 (3.0%)	0 (0.0%)	–	–
Malignant schwannoma	1 (3.0%)	0 (0.0%)	–	–
Metastasis from renal cell carcinoma	1 (3.0%)	0 (0.0%)	–	–
Metastatic melanoma	1 (3.0%)	0 (0.0%)	–	–
Neurofibroma	0 (0.0%)	1 (2.8%)	1	1.9%

Nodular fasciitis	1 (3.0%)	0 (0.0%)	1	1.9%
Post-injection gluteal soft tissue swelling	1 (3.0%)	0 (0.0%)	1	1.9%
Rhabdomyosarcoma	1 (3.0%)	0 (0.0%)	–	–
Sebaceous cyst	0 (0.0%)	4 (11.1%)	4	7.7%
Soft tissue sarcoma	1 (3.0%)	0 (0.0%)	–	–
Squamous cell carcinoma	1 (3.0%)	0 (0.0%)	–	–
Subacromial bursitis	1 (3.0%)	0 (0.0%)	1	1.9%
Subcutaneous calcinosis	0 (0.0%)	1 (2.8%)	1	1.9%
Supraspinatus tear with subdeltoid bursitis	1 (3.0%)	0 (0.0%)	1	1.9%
Synovial sarcoma	1 (3.0%)	0 (0.0%)	–	–
Vascular malformation	0 (0.0%)	1 (2.8%)	1	1.9%

Table 4: Distribution of USG findings in benign subjects

		BENIGN	
		N	%
USG Findings	Ill-defined	18	34.6%
	Well defined	34	65.4%
Number	Single	51	98.1%
	Two	1	1.9%
Echogenicity	Anechoic	2	3.8%
	Heterogenous hypoechoic	10	19.2%
	Heterogenously hyperechoic	2	3.8%
	Heterogenously hypoechoic	14	26.9%
	Hyperechoic	8	15.4%
	Hypoechoic	10	19.2%
	Hypoechoic with hyperechoic	1	1.9%
	Iso to hypoechoic	1	1.9%
	Isoechoic	2	3.8%
	Tubular hypoechoic	2	3.8%

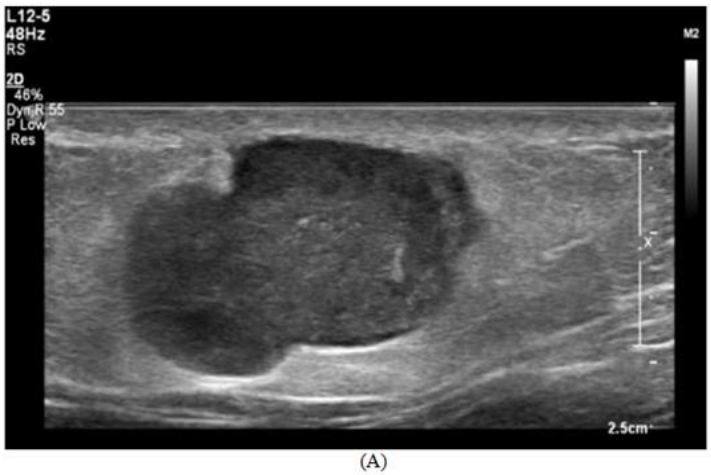
Table 5:- Distribution of Color Doppler Findings in benign subjects

		N (%)
Color Doppler Findings	High Vascularity	12 (23.07%)
	Mild Vascularity	5 (9.6%)
	No Vascularity	31 (59.6%)
	Peripheral Vascularity	4(7.7%)
Resistivity Index#	Mean ± SD Median (Min, Max)	0.56 ± 0.135 0.56 (0, 1)
Pulsatility Index#	Mean ± SD Median (Min, Max)	1.14 ± 0.356 1.10 (1, 3)

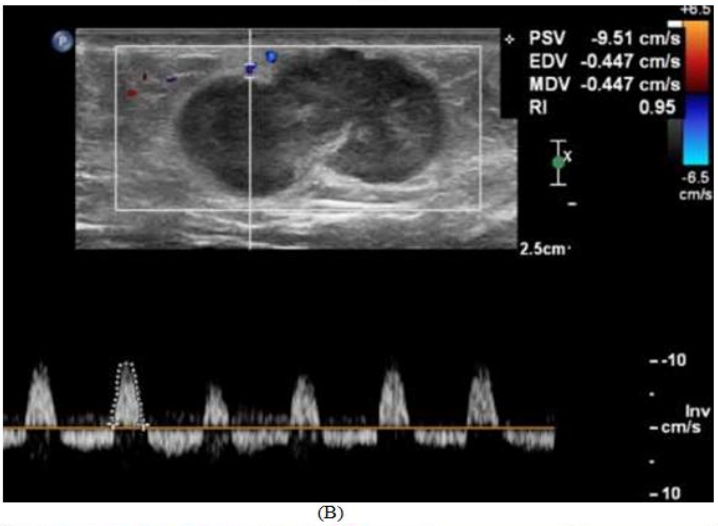
ILLUSTRATIVECASES

CASE–1 :

Clinical History: Primary case of carcinoma cervix. The patient presented with swelling in the left anterior abdominal wall for 3months.



(A)



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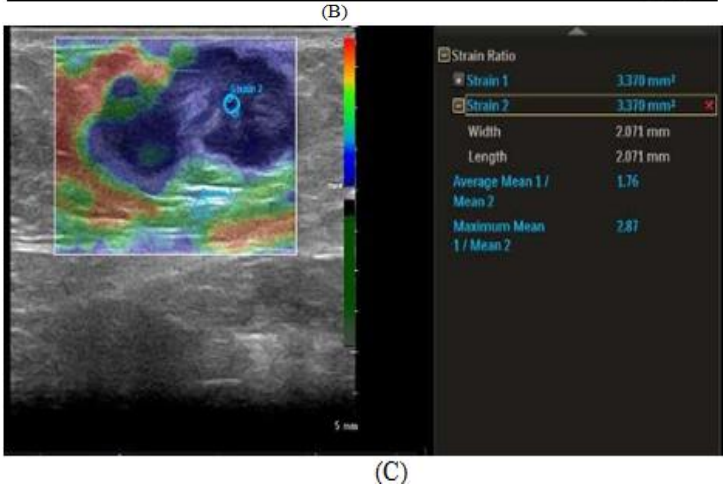

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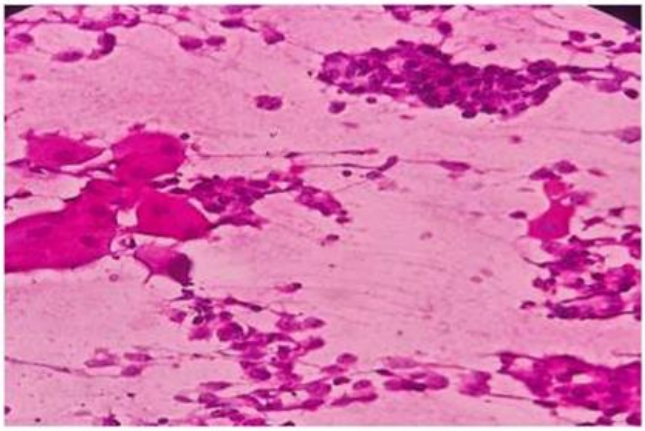
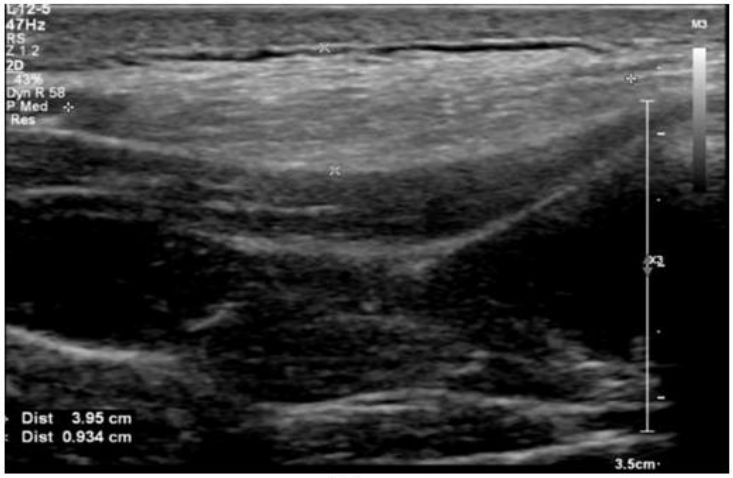


(D)

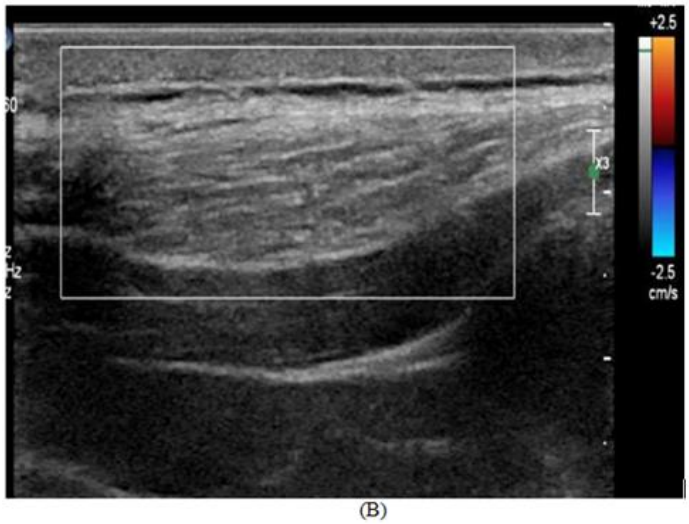
FIGURE 1 (A, B, C, D): Grey scale image showing a well-defined, lobulated heterogeneously hypoechoic lesion in the left anterior abdominal wall in the subcutaneous plane. There are no calcifications or cystic changes. The lesion shows peripheral vascularity on Color Doppler. Tsukuba score (TES Score) –4 (Blue). The Strain Ratio is 2.87. HPE: Tumor cells are large, ovoid with increased N:C ratio, round to oval nucleus exhibiting moderate nuclear atypia, dense coarse granular chromatin, one to two nucleoli and moderate dense eosinophilic cytoplasm. Positive for malignancy, features suggestive of Metastatic poorly differentiated carcinomatous deposits, possibly squamous- Anterior abdominal wall deposit. In a primary case of carcinoma cervix, the above features are suggestive of ABDOMINALWALLMETASTATIC DEPOSIT (Malignant Lesion).

Case-2 :

Clinical History: Young patient presented with swelling and pain in the posterior chest wall since 5years.



(A)



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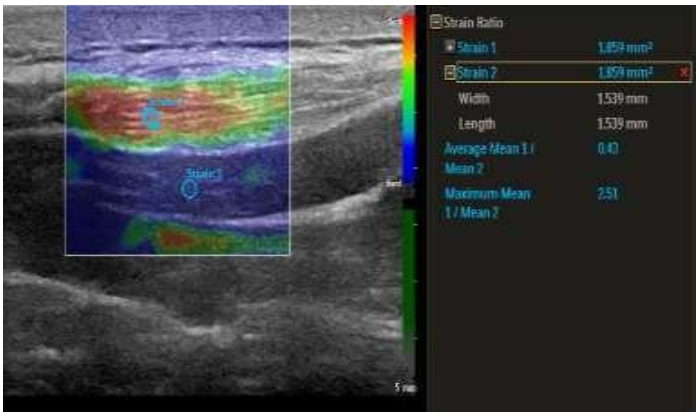

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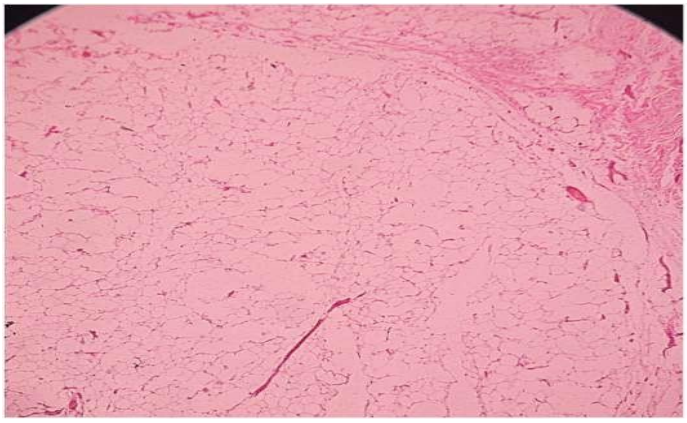
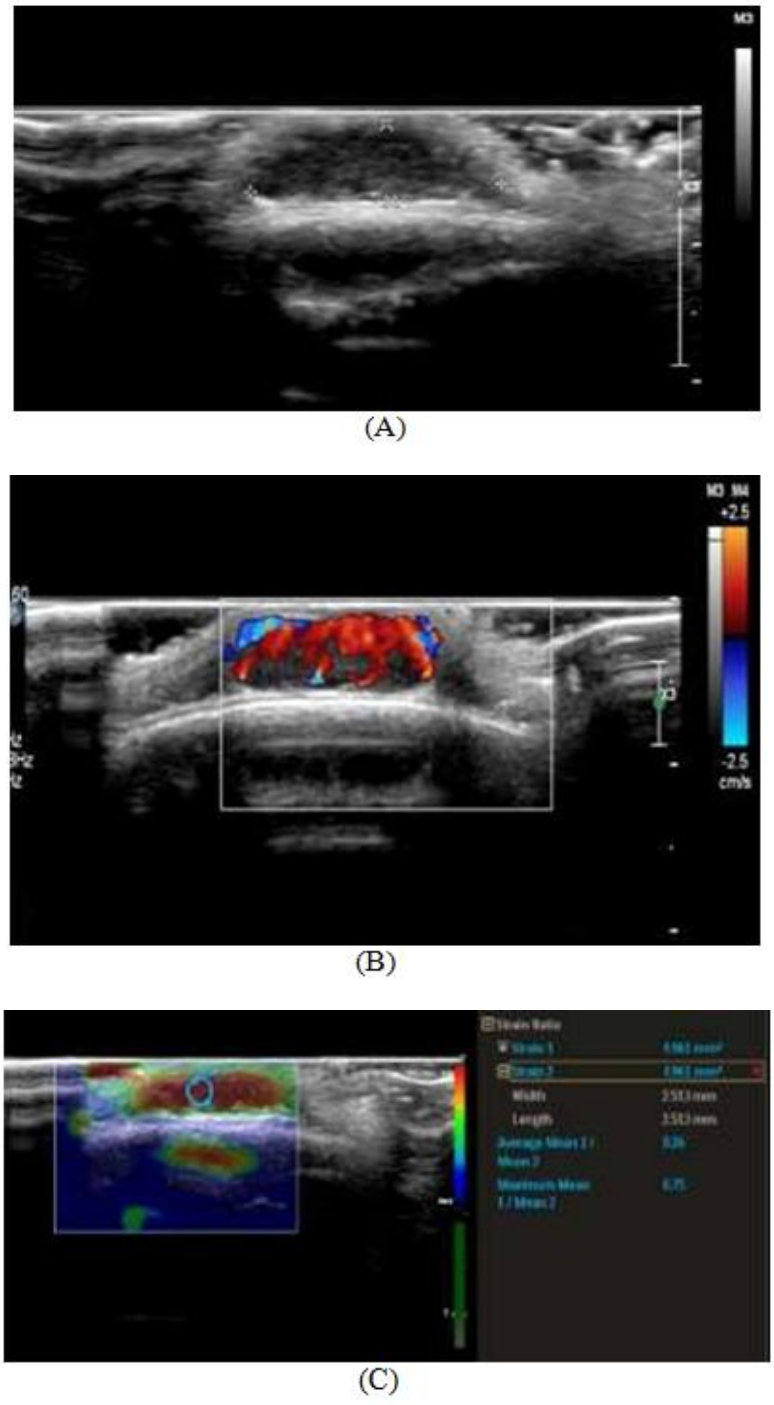


(D)

FIGURE 2 (A, B, C, D): Grey scale B-mode image showing well defined, encapsulated lesion with echo pattern identical to fat (hyperechoic) noted at the site of swelling in the posterior chest wall in subcutaneous plane. The lesion shows mild compressibility. The Lesion shows no vascularity on Color Doppler. Tsukuba score (TES Score) – 1(Green). Strain ratio of 2.51. Histopathology shows a thin capsule and underlying lobules of mature adipose cells separated by delicate fibrous septa. The above features of the lesion are suggestive of LIPOMA (Benign Lesion).

CASE-3 :

Clinical history: 2 years child present with swelling over the scalp since birth.



(A)

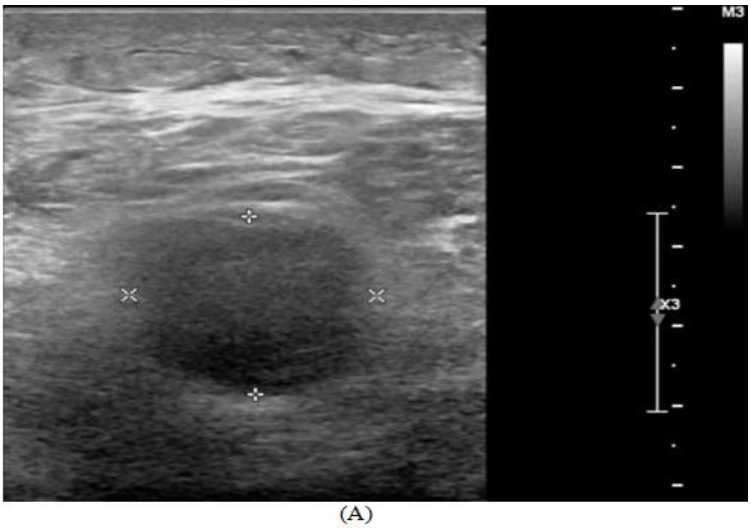
(B)

(C)

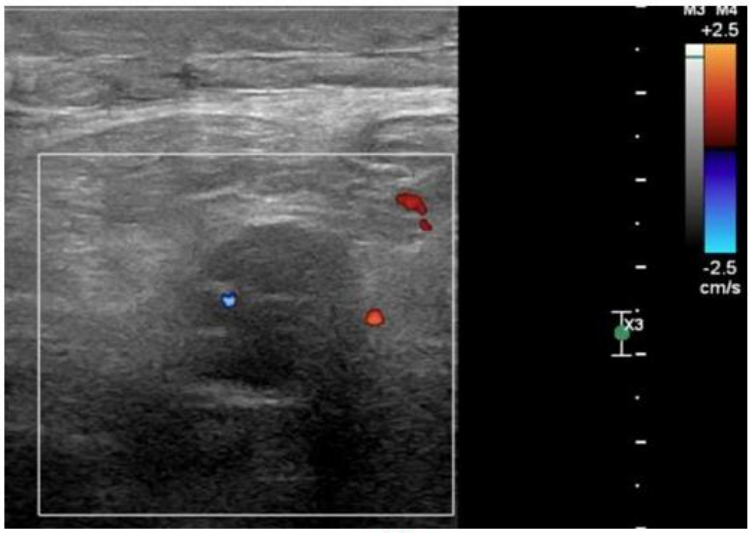
FIGURE 3 (A, B, C) -Greyscale image showing well-defined, heterogeneously hypoechoic lesion in the subcutaneous plane over the scalp region showing significant flow noted on Colour Doppler. No calcifications or cystic changes. Tsukuba score – 1(BGR pattern). Strain ratio was 0.75. The above features are suggestive of VASCULAR MALFORMATION (AVM) (Benign Lesion).

CASE-4:

Clinical history: 22-year male patient presented with swelling and excruciating pain in the left lower limb since1 year.



(A)



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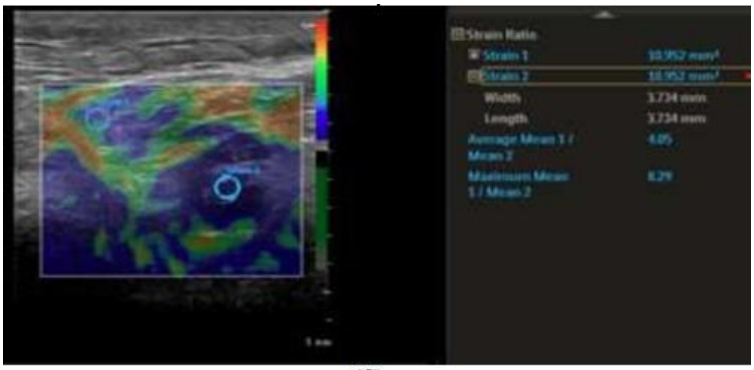

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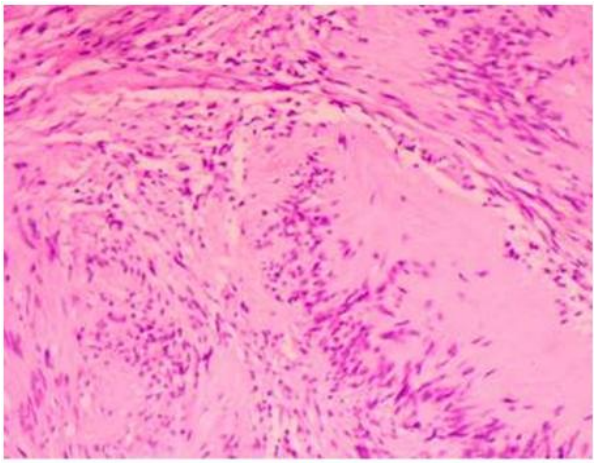
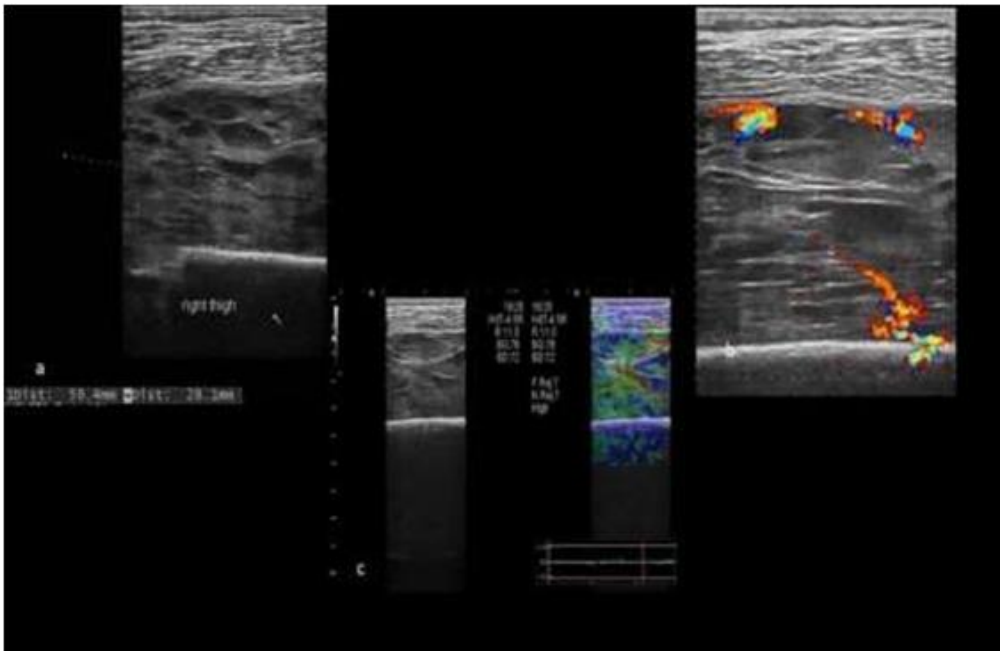


(D)

FIGURE 4 (A, B, C, D) -Grey scale image showing Ill-defined, hypoechoic mass lesion with its clear borders arising from the fascicle noted along the course of the left sciatic nerve in the posterior aspect of thigh in the intermuscular plane showing vascularity on Color Doppler. The lesion was moderately compressible. Tsukuba Elasticity score was 4(BLUE). Strain ratio was 8.2. Histopathology shows whorls of dense cellular (Antoni A) and loosely cellular areas (Antoni B) with nuclear palisading. The above features are suggestive of PERIPHERAL NERVE SHEATH TUMOR - SCHWANNOMA (Indeterminate Lesion).

CASE-5

Clinical history: Elderly patient presented with mass in the right thigh region since 5-6 year.



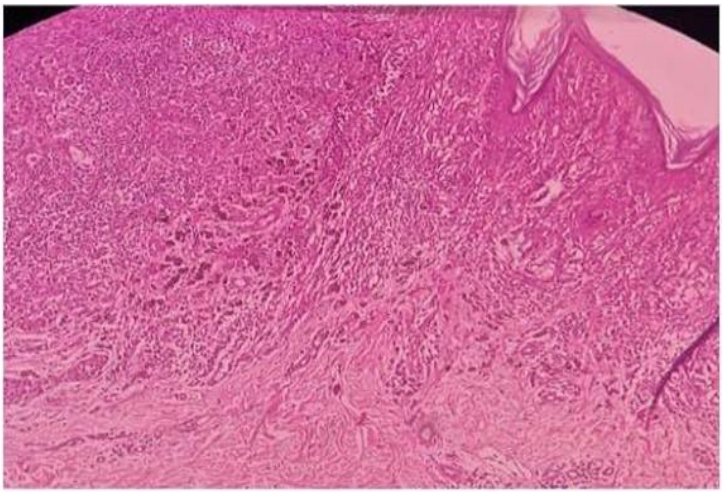
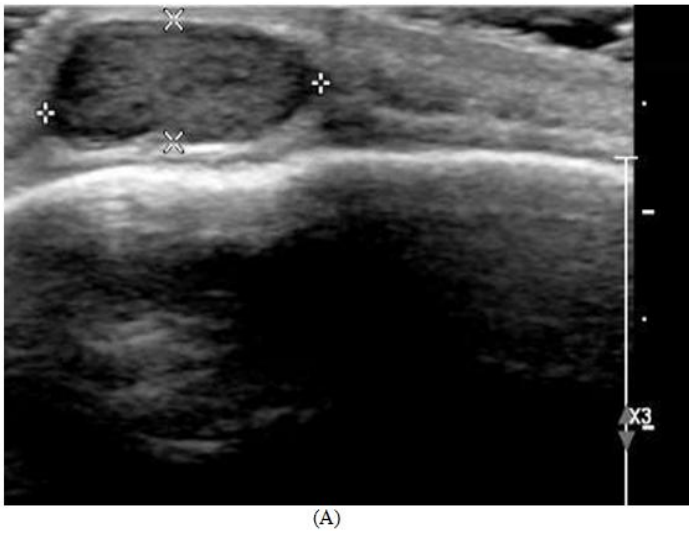


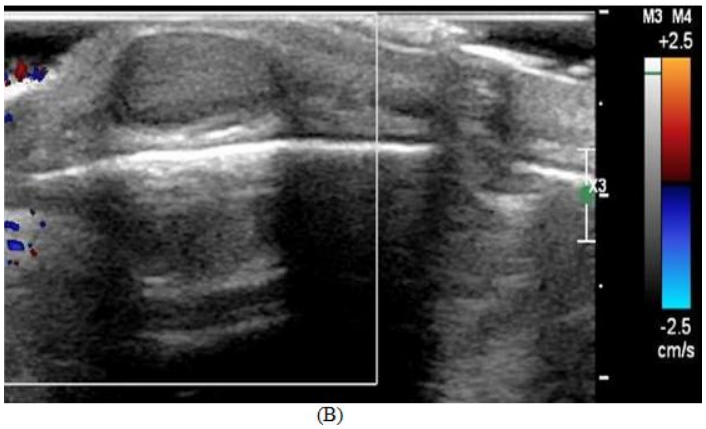
FIGURE 5 (a, b ,c,d) -Grey scale image showing ill-defined, hypoechoic to iso-echoic, mass lesion in the anterior aspect of right thigh showing few cystic areas within and vascularity on Color Doppler. Tsukuba Elasticity score was 4 and the average Strain Ratio is 3.9. Histopathology slides shows tumor cells resembling epithelioid cells with pleomorphic nuclei. Many tumor cells contain fine granular melanin pigment. The above features are suggestive of MELANOMA (Malignant Lesion).

CASE-6:

Clinical history: 28 year male patient presenting with swelling over the scalp since 5-6 years.



(A)



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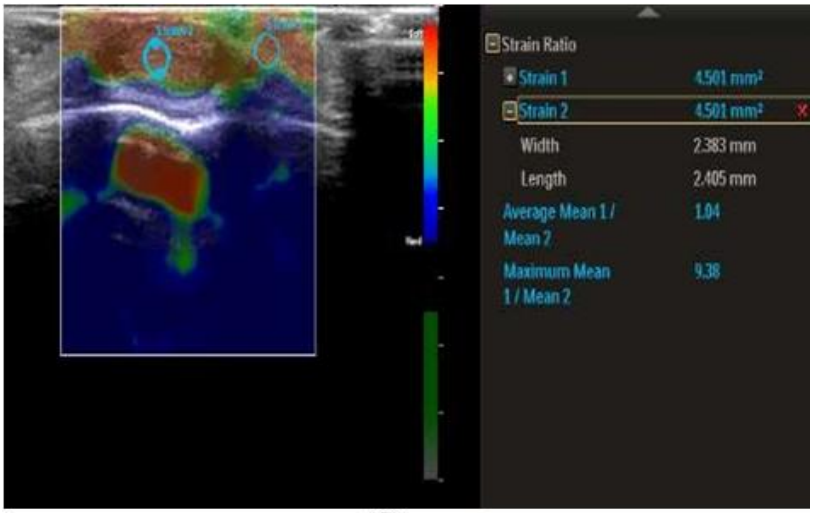
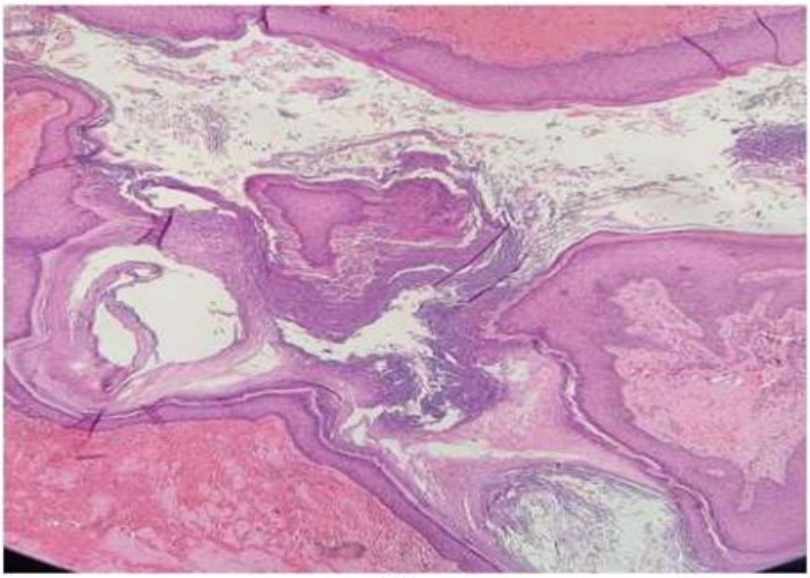


(C)



(D)

FIGURE 6: (A,B,C,D) -Greyscale image showing well defined, heterogeneously hypoechoic mass lesion in the deep subcutaneous plane over the scalp region with no vascularity on Color Doppler. Tsukuba Elasticity score was 1. The strain ratio was 1. Histopathology shows subepidermal cyst is present lined by stratified squamous epithelium with a granular layer. Cyst contain abundant keratin flakes. The above features are suggestive of EPIDERMAL CYST (Benign Lesion).

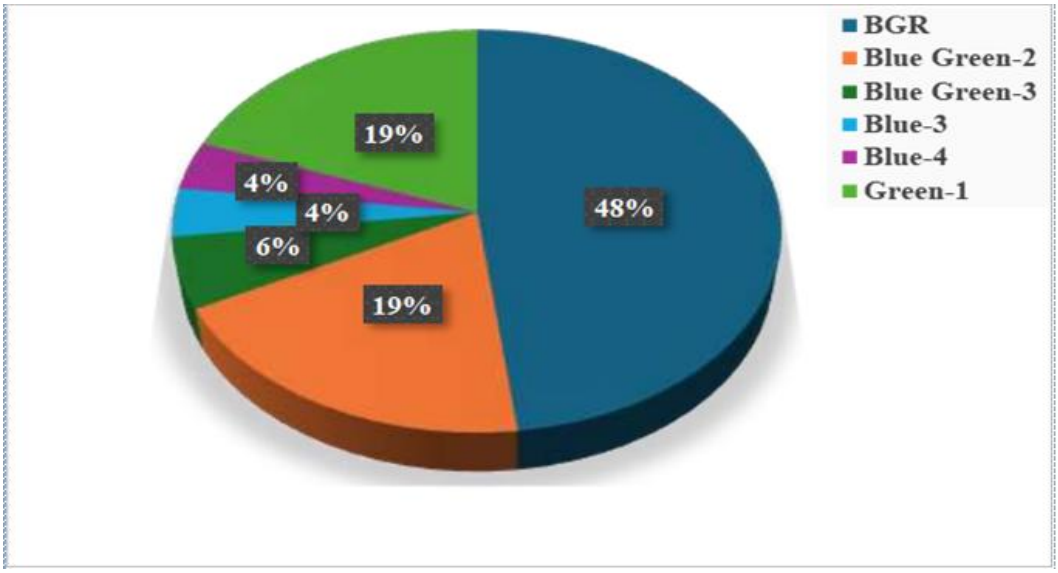


Figure 7 :- Graph showing Distribution of TES Score in benign subjects

Table:6 USG Findings, Echogenicity & Site Distribution in Malignant Subjects (N = 17)

Parameter	Category	N	%
USG Findings	Ill-defined	15	88.2%
	Well-defined	2	11.8%
Number of Lesions	Single	16	94.1%
	Two	1	5.9%
Echogenicity	Heterogeneous hypoechoic	1	5.9%
	Heterogeneous with cystic component	1	5.9%
	Heterogenously hypoechoic	8	47.1%
	Homogenously hypoechoic	1	5.9%
	Hypoechoic	3	17.6%
	Iso to hypoechoic	1	5.9%
	Lobulated heterogeneously hypoechoic	1	5.9%
	Lobulated heterogeneously hypoechoic mass	1	5.9%
Site Distribution	Axilla	1	5.9%
	Back	1	5.9%
	Foot	1	5.9%
	Lateral aspect of left knee	1	5.9%
	Left angle of mouth	1	5.9%
	Left calf	1	5.9%
	Left gluteal region	1	5.9%
	Left leg tibial aspect	1	5.9%
	Little finger	1	5.9%
	Lower left femur	1	5.9%
	Right arm	1	5.9%
	Right calf	1	5.9%
	Right forearm	1	5.9%
	Right leg	1	5.9%
	Right thenar eminence	1	5.9%
	Sacral region	1	5.9%
	Upper chest	1	5.9%

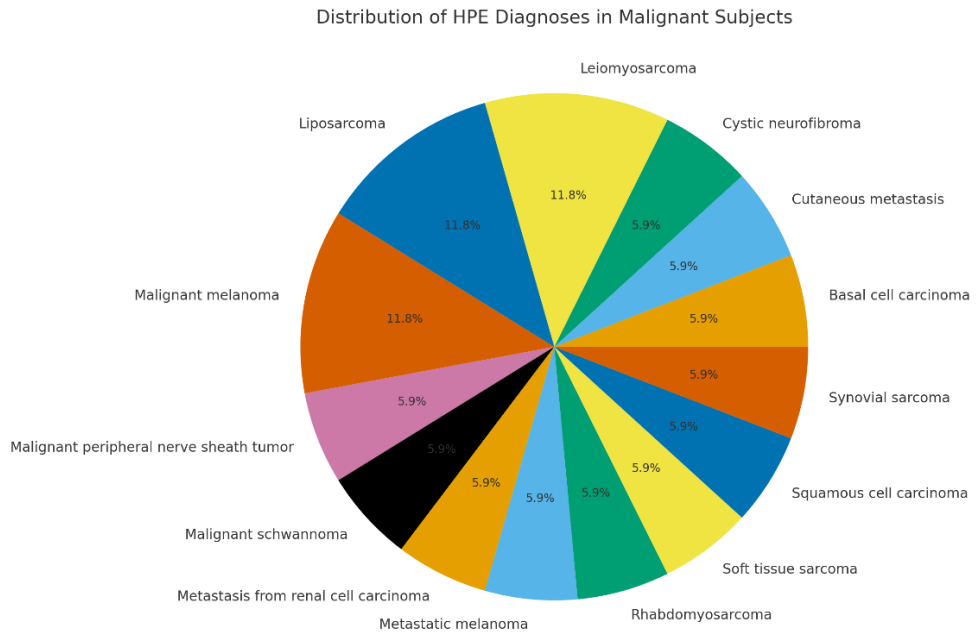


Figure 8:- Graph showing Distribution of subjects according to HPE in malignant subjects

Table; 7 Distribution of Color Doppler Findings, Vascular Indices, and TES Score in Malignant Subjects

Parameter	Category	N (%) / Value
Color Doppler Findings	High Vascularity	10 (58.8%)
	Mild Vascularity	3 (17.6%)
	No Vascularity	2 (11.7%)
	Peripheral Vascularity	2 (11.7%)
Resistivity Index (RI)	Mean ± SD	0.79 ± 0.121
	Median (Min, Max)	0.8 (0.5, 1.0)
Pulsatility Index (PI)	Mean ± SD	1.58 ± 0.217
	Median (Min, Max)	1.6 (1.1, 1.84)
TES Score	Blue-4	13 (76.4%)
	Blue Green-3	3 (17.6%)
	Blue-5	1 (5.8%)

Table: 8 Association Between Benign and Malignant Lesions Based on USG and Color Doppler Characteristics

Parameter	Category	Benign N (%)	Malignant N (%)	P value
USG Findings	Ill-defined	18 (34.6%)	15 (88.2%)	**<0.001**
	Well-defined	34 (65.4%)	2 (11.8%)	
Color Doppler Findings	High Vascularity	12 (23.07%)	10 (58.8%)	**<0.001**
	Mild Vascularity	5 (9.6%)	3 (17.6%)	
	No Vascularity	31 (59.6%)	2 (11.7%)	
	Peripheral Vascularity	4 (7.7%)	2 (11.7%)	

Table 9:- Association between Benign and Malignant lesions with TES score

	Malignant	Benign	P value
BGR	0(0%)	25 (48.07%)	<0.001
Blue Green-2	0(0%)	10 (19.2%)	
Blue Green-3	3 (17.6%)	3 (5.7%)	
Blue-3	0(0%)	2 (3.8%)	
Blue-4	13 (76.4%)	2 (3.8%)	
Blue-5	1 (5.8%)	0(0%)	
Green-1	0(0%)	10 (19.2%)	

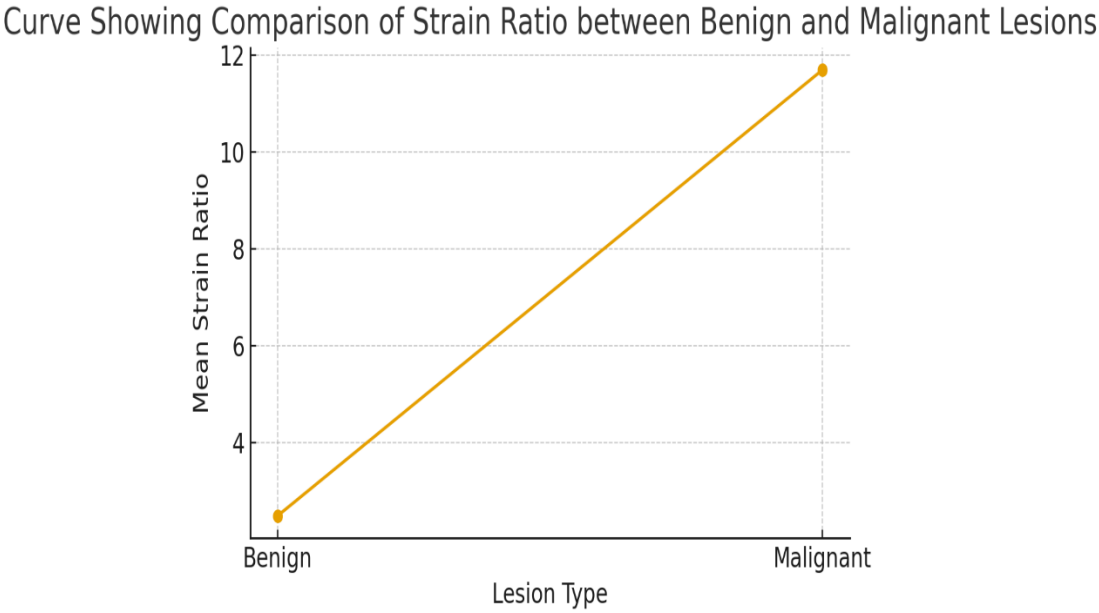


Figure 9: Curve Showing Comparison of Mean Strain Ratio Between Benign and Malignant Lesions

DISCUSSION

Superficial soft tissue lesions present a diagnostic challenge due to their heterogeneous nature and overlapping clinical presentations. Accurate differentiation between benign and malignant lesions is essential for guiding management and avoiding unnecessary interventions [1–3]. In the present study, a multimodal ultrasound approach integrating B-mode USG, color Doppler, and strain elastography was employed to assess these lesions and correlate findings with histopathology.

B-mode ultrasound remains the cornerstone for initial evaluation of superficial soft tissue lesions. Our findings indicate that benign lesions predominantly exhibited well-defined margins (65.4%) and varied echogenicity, with hypoechoic and heterogeneous hypoechoic patterns being most common. In contrast, malignant lesions were largely ill-defined (88.2%) and heterogeneous hypoechoic (47.1%), reflecting their aggressive growth and tissue infiltration [4–6]. This aligns with prior studies demonstrating that margin irregularity and heterogeneous echotexture on B-mode imaging are strong indicators of malignancy [7,8].

Color Doppler imaging further enhanced lesion characterization by providing insight into vascularity. In our cohort, 58.8% of malignant lesions exhibited high vascularity, compared with only 23.07% of benign lesions. Peripheral vascularity was more common in benign lesions, consistent with findings reported by Chiou et al. and Ahuja et al., where hypervascularity with irregular flow patterns strongly correlated with malignancy [6,9]. The resistivity index (RI) and pulsatility index (PI) were significantly higher in malignant lesions (mean RI: 0.79, mean PI: 1.58) compared to benign lesions (mean RI: 0.56, mean PI: 1.14), reflecting increased vessel stiffness and neovascularization associated with malignant transformation [10,11].

Strain elastography provided an additional, quantitative assessment of tissue stiffness. The mean strain ratio (SR) was significantly higher in malignant lesions compared to benign lesions, supporting previous reports that stiffer lesions are more likely to be malignant [12–14]. TES score distribution revealed that the majority of malignant lesions scored Blue-4 or Blue-5, whereas benign lesions predominantly scored BGR or Blue Green-2, reinforcing the utility of elastography in distinguishing lesion types. Similar observations have been documented in studies by Taljanovic et al. and Itoh et al., who reported that elastography could reliably differentiate between benign and malignant soft tissue masses based on strain ratios and color scoring [9,12].

The combination of B-mode, color Doppler, and strain elastography increased diagnostic confidence and accuracy. When used in isolation, each modality provided valuable information, but the integrated approach allowed for a more comprehensive assessment of lesion morphology, vascularity, and stiffness. This synergistic evaluation resulted in a higher correlation with histopathological findings, confirming that multimodal ultrasonography can serve as a reliable, non-invasive diagnostic tool [11,15–17].

Site distribution analysis in this study revealed that malignant lesions were observed in varied anatomical locations, emphasizing that lesion location alone is insufficient for malignancy prediction. Similarly, benign lesions such as lipomas, cysts, and keloids were common in extremities and trunk, reflecting typical epidemiological patterns described in previous studies [5,6,18].

Overall, our study supports the growing evidence that an integrated ultrasonographic approach can provide detailed morphologic, hemodynamic, and mechanical information about superficial soft tissue lesions. The findings demonstrate that such an approach can assist clinicians in preoperative planning, guiding biopsy decisions, and potentially reducing unnecessary invasive procedures.

CONCLUSION

Integrated B-mode ultrasound, colour Doppler, and strain elastography reliably differentiate benign from malignant superficial soft tissue lesions. Malignant lesions were mostly ill-defined, heterogeneous, hypervascular, and stiffer on elastography, whereas benign lesions were well-defined, less vascular, and softer. Multimodal imaging correlated strongly with histopathology, supporting its role as a non-invasive, accurate tool for diagnosis and treatment planning.

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