Role of Doppler ultrasound in the evaluation of superficial soft tissue lesions

Andrew S. Gerges[a], Hassan I. Megalli[b], Abeer H. Ali[b]

[a]Department of Radiology, Health Insurance Hospital, [b]Department of Diagnostic Radiology, Faculty of Medicine, Assiut University, Assiut, Egypt

Correspondence to Andrew S. Gerges, BSC, Department of Radiology, Health Insurance Hospital, Assiut 71111, Egypt.
Tel: +20 127 753 3301;
Fax No: 088/2322610;
e-mail: andrewsamir90@yahoo.com

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Objectives
To evaluate the role of Doppler ultrasound (DUS) in the characterization of superficial soft tissue lesions using histopathological examination as a gold standard.
Patients and methods
Forty patients, mean age 37.43 ± 16.9 years complaining of superficial soft tissue swelling in any region of the body were prospectively included. Gray scale evaluation was performed and then color Doppler interrogation was applied to evaluate its vascularity and finally spectral Doppler analysis. DUS findings were subjected to histopathologic correlation.
Results
Five malignant and 35 benign lesions were histopathologically diagnosed. There was strong agreement ($K = 0.89$) between DUS impression and histopathological diagnosis ($P < 0.001$).
Conclusions
DUS can characterize the nature of superficial soft tissue lesions and discriminate benign from malignant.

Keywords:
Doppler ultrasound, end-diastolic velocity, peak systolic velocity, resistivity index, superficial soft tissue

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Introduction

A wide variety of superficial soft-tissue lesions is commonly seen in daily clinical practice [1,2]. The patient is occasionally referred to imaging for further and more detailed assessment of lesions [1].

Multiple imaging modalities can be used for the evaluation of superficial soft-tissue lesions, such as plain radiograph, Doppler ultrasonography (DUS), computed tomography (CT), MRI, or angiography [1,2]. Compared with other imaging modalities, DUS is a readily available, noninvasive, relatively inexpensive, and easily repeatable radiation-free imaging modality [3]. US examination is a powerful tool in determining the presence and the solid or cystic nature of a soft tissue lesion and its relation to the surrounding anatomical structures. Furthermore, US can help in differentiating localized mass from diffuse edema [3,4].

In the evaluation of superficial soft tissue lesions, DUS has many advantages over MRI including lack of partial volume averaging effects, and the short examination time hence reducing the motion artifacts, which may occur in noncooperative patients and children. In addition, real-time and dynamic interpretation of the lesion is an important advantage of US and is mandatory for accurate diagnosis and subsequently correct management [5].

The gray scale US has high sensitivity in the detection and growth pattern characterization of superficial soft tissue lesions, but some reports in the literature concluded that it cannot differentiate benign from malignant lesions [6–9]. The recent advances in digital US technology with the use of high-resolution machines and high-frequency transducers allowed a more detailed evaluation of the superficial tissue lesions [1,3]. Also, the introduction of color Doppler US (CDUS) and spectral Doppler US (SDUS) has improved the ability to assess the degree and pattern of vascularization of soft tissue lesions [9]. Although the criteria of malignancy are variable, vascular irregularities can be detected within malignant lesions [2]. Peripheral vascularity can also be used to identify the boundaries of the mass and in determining whether a very hypoechoic nodule is a purely cystic or solid lesion, which could be a useful impression before biopsy [10].

The study aims to evaluate the role of DUS in the characterization of superficial soft tissue lesions using histopathological examination as a gold standard.

Patients and methods

Study design and patient population

This prospective cohort study was approved by our Institutional Ethics Committee (Assiut University Ethics Review Board with IRB: 17101481). In the period between May 2018 and May 2020, all patients referred to the Diagnostic Radiology Department of Assiut University Hospitals with a clinically palpable superficial soft tissue swelling were prospectively studied. Patients with recurrent postoperative superficial soft tissue lesions were excluded, as this may change the US findings of the lesion. Patients who did not have histopathological examinations were also excluded.

All patients of the study were subjected to through clinical history taking, clinical evaluation, and DUS examination including gray scale evaluation, color Doppler evaluation, and spectral Doppler assessment with measurement of the peak systolic velocity (PSV) and end-diastolic velocity (EDV) with calculation of the resistivity index (RI). Finally, the US diagnosis was correlated with histopathological results.

Patient preparation

Patients were instructed to avoid nicotine products like cigarettes for 24 h before the examination because nicotine causes vasoconstriction, which might be misinterpreted as a pathological constriction [11]. At the time of examination, the patient was asked to change into a hospital gown, according to the area of the body to be examined.

Patient position

The examination was performed while the patient was standing, sitting, or lying on the examination table, facing the examiner, and the area to be examined exposed with relaxed muscles to avoid overbulging or pressure with subsequent change in the shape or vascularity of the lesion and breath-hold was performed for a time to reduce movement artifacts.

Doppler ultrasound examination

Technical parameters

Using musculoskeletal parameters on the same US machine (Philips-Affiniti-50G; Philips Medical Systems, Nederland B.V.), all patients were examined by the same radiologist (A.S.G.) under supervision of one of the two senior radiologists (H.I.M. and A.H.A. with 20 and 10 years of experience, respectively). Depending on the size and depth of the lesion, the curved array or linear probe was used with frequencies of 3.5–5 or 7.5–10 MHz. During CDUS evaluation, the scale level was reduced and the color gain was increased with avoidance of pressure to detect any low-velocity flows. For spectral analysis, low-wall filters and low pulse repetition frequency were used.

Technique of Doppler ultrasound scanning

Using the gray scale, each lesion was evaluated for its morphological pattern, margins, echogenicity, texture, and composition. CDUS interrogation was performed in each lesion to assess for vascularity. Vascularity was assessed within each lesion. SDUS analysis was then applied on vascular lesions with measurement of PSV and EDV and calculation of RI. Waveforms were recorded at different sites within each lesion and a minimum of three measurements was performed. When different values were found within the same lesion, the highest values were considered for evaluation.

Image analysis

The images of each patient were stored separately on the US device's DICOM viewer (Philips US DICOM viewer R2.1 Version 2 Level 1). At a later date, the images of all patients were assessed independently by the two supervising radiologists (H.I.M. and A.H.A.). Final consensus was obtained in case of initial disagreement.

On gray scale images, the shape of the lesion was divided into round, oval, ovoid, or irregular. According to their size, the lesions were classified as small (<1 cm), medium (1–5 cm), or large (>5 cm). The lesion margins were assessed as well defined (clear-cut with a thin capsule-like), ill defined (uncertain margin in relation to the adjacent normal tissue), or infiltrated (certain irregular margin with a wide transitional zone). Echogenicity was defined as hypoechoic, hyperechoic, isoechoic, or anechoic relative to the adjacent muscle tissue. Internal texture was classified as homogeneous or heterogeneous while composition was characterized as solid, cystic, or mixed [12].

In CDUS images, the lesions were divided into avascular or vascular. Furthermore, vascularity was classified as low or high according to the number of afferent vessels (<3 vs. ≥3 afferent vessels). Finally, PSV and EDV were recorded from the spectral waveforms of SDUS images, and the RI was calculated (RI = PSV minus EDV divided by PSV) [13].

Histopathological correlation

All lesions were subjected to histopathological examination after surgical excision in seven patients, US-guided fine-needle aspiration in 23 patients, while US-guided Tru-Cut needle biopsy was done for 10 patients. Finally, the DUS impression of each lesion was compared with its histopathological result.

Statistical analysis

Data was collected and analyzed using SPSS (Statistical Package for the Social Sciences, version 20; IBM, Armonk, New York, USA). Nominal data was expressed in the form of frequency and percentage while continuous data was presented as range and mean ± SD. The degree of agreement between histopathological and DUS diagnoses of the lesions was assessed by *K* degree. The predictive power in differentiating benign from malignant lesions was assessed by the receiver-operating characteristics (ROC) curve. The level of confidence was kept at 95% and *P* value was considered significant if less than 0.05.

Results

Patients' demographics

There was female predominance (60%) and 50% of the patients were 31:50 years old. Upper and lower limbs were the most affected regions (n = 10 and 11 patients, respectively) and 72.5% of the cases were referred from the orthopedic clinic (Table 1).

Doppler ultrasound findings of the studied lesions

Gray scale findings

The mean width, length, and depth of the studied lesions were 3.67 ± 1.65, 2.52 ± 1.34, and 3.26 ± 1.49 cm, respectively and 50% of them were oval in shape. The margin was well defined in 57.5% of lesions. The lesions were hypoechoic in 65% of cases, heterogeneous in 57.5%, and the majority (82.5%) had solid consistency (Table 2).

Color and spectral Doppler findings

The vascularity was observed in 19 (47.5%) lesions and was high in 12 of them and low in the remaining seven lesions. The mean of PSV, EDV, and RI were 17.5 ± 10.4 cm/s, 5.8 ± 1.8 cm/s, and 0.6 ± 0.1, respectively (Table 3).

Correlation between Doppler ultrasound impression and histopathological diagnoses

The most frequent histopathological diagnoses were hematoma and neurofibroma (each of them was detected in 12.5% of cases), followed by lipoma and abscess (each of them in 10% of cases). The DUS diagnosis agreed with the histopathological report in all cases except one of the two pathologically proved cases of non-Hodgkin lymphoma, one of the two cases of giant cell tumor of the tendon sheath, and one case of metastatic deposit at the iliac bone that was incorrectly diagnosed as chondrosarcoma (*K* = 0.89, $P < 0.001$) (Table 4).

Table 1 Demographic data of the studied patients

Data	*n*=40
Age (years)	37.43±16.90
Range	8 days-70 years
Age group (year) [*n* (%)]	
<10	3 (7.5)
11-20	4 (10)
21-30	6 (15)
31-40	9 (22.5)
41-50	11 (27.5)
>50	7 (17.5)
Sex	
Male	16 (40)
Female	24 (60)
Referral clinic	
General surgery	11 (27.5)
Orthopedic surgery	29 (72.5)
Site	
Head and neck region	7 (17.5)
Upper limb	10 (25)
Lower limb	11 (27.5)
Abdominal wall	3 (7.5)
Spinal and back region	8 (20)

Table 2 Gray scale characteristics of the studied lesions

	n=40
Shape	
Oval	20 (50)
Rounded	13 (32.5)
Ovoid	6 (15)
Irregular	1 (2.5)
Size	
Width (cm)	3.67±1.65
Length (cm)	2.52±1.34
Depth (cm)	3.26±1.49
Margin	
Well defined	23 (57.5)
Ill-defined	16 (40)
Speculated	1 (2.5)
Echogenicity	
Isoechoic	5 (12.5)
Hyperechoic	3 (7.5)
Hypoechoic	26 (65)
Anechoic	6 (15)
Texture	
Homogeneous	17 (42.5)
Heterogeneous	23 (57.5)
Composition	
Cystic	5 (12.5)
Solid	33 (82.5)
Mixed	2 (5)

Data expressed as *n* (%) and mean±SD.

The accuracy of Doppler ultrasound in characterizing the nature of the studied lesions

When compared with histopathological results, DUS showed 89.7% sensitivity and 83.3% specificity in the diagnosis of superficial soft tissue lesions with an overall accuracy of 97.5% ($P < 0.001$) (Table 5).

Gray scale, color, and spectral Doppler features in the differentiation between pathologically proved benign and malignant lesions

There was no significant difference between the benign and malignant lesions in terms of gray scale and CDUS features ($P > 0.05$). SDUS parameters were significantly higher in malignant than in benign lesions (all $P < 0.001$). ROC curves analysis was created for the values of PSV, EDV, and RI and revealed that PSV more than 15 cm/s, EDV more than 6.4 cm/s, and RI more than 0.72 were the most suitable cutoff points for the differentiation between benign and malignant lesions with an accuracy of 71.4, 81, and 81%, respectively (all $P < 0.001$) (Table 6, Figs. 1-4).

Table 3 Doppler ultrasound findings of the studied lesions

	n=40
Vascularity	
Avascular	21 (52.5)
Vascular	19 (47.5)
Low vascularity	7 (17.5)
High vascularity	12 (30)
PSV (cm/s)	17.5±10.4
EDV (cm/s)	5.8±1.8
RI	0.6±0.1

Data expressed as *n* (%) and mean±SD. EDV, end-diastolic velocity; PSV, peak systolic velocity; RI, resistivity index.

Discussion

Accurate management of superficial soft tissue lesions requires evaluation of their location, morphology, size, margins, composition, vascularity, and relation to the surrounding anatomical structures [1,12–14]. Currently, DUS plays an important role in the investigation of superficial soft tissue masses because it is an easily available, less time-consuming, less expensive, noninvasive, and radiation-free method. DUS can reach the correct diagnosis of a specific type of lesion or exclude it, provide a short list of differential diagnosis, and determine the possibility of malignancy [3,13].

In a relatively similar result to a previous report [2], ~12.2% of the superficial soft-tissue lesions included in the present study were malignant.

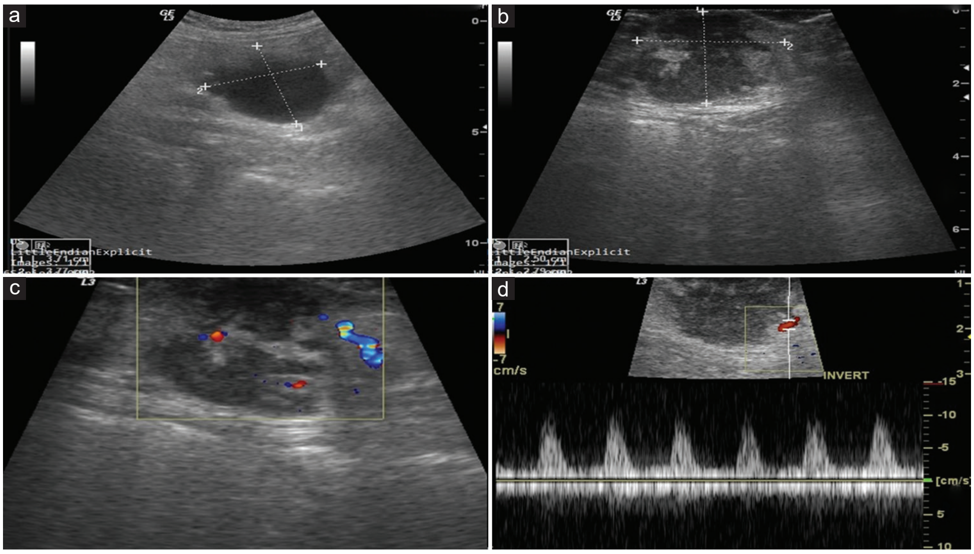
In concordance with two previous studies [13,15], DUS examination in the current study revealed a high overall accuracy (97.5%) in diagnosing various superficial soft tissue lesions namely hematoma, neurofibroma, lipoma, abscess, abscess, sebaceous cyst, schwannoma, periosteal osteosarcoma, non-Hodgkin lymphoma, giant cell tumor of the tendon sheath,

Table 4 Agreement between Doppler ultrasound impression and pathological diagnoses

Pathological diagnoses	Ultrasound diagnoses		Total (*n*=40)
	Correct	Incorrect	
Hematoma	5	0	5 (12.5)
Neurofibroma	5	0	5 (12.5)
Lipoma	4	0	4 (10)
Abscess	4	0	4 (10)
Sebaceous cyst	2	0	2 (5)
Schwannoma	2	0	2 (5)
Para-osteal osteosarcoma	2	0	2 (5)
Non-Hodgkin lymphoma	1	1	2 (5)
Giant cell tumor of the tendon sheath	1	1	2 (5)
Baker's cyst	2	0	2 (5)
Serous collection	1	0	1 (2.5)
Pleomorphic adenoma	1	0	1 (2.5)
Osteogenic sarcoma	1	0	1 (2.5)
Spinal meningocele	1	0	1 (2.5)
Morel-Lavallée lesion (chronic hematoma)	1	0	1 (2.5)
Metastatic deposit at the iliac bone	0	1	1 (2.5)
Inflammatory granulation tissue	1	0	1 (2.5)
Fibroma of the tendon sheath	1	0	1 (2.5)
Cellulitis	1	0	1 (2.5)
Cavernous lymphangioma	1	0	1 (2.5)
Total	37 (92.5)	3 (7.5)	40 (100)
Kappa degree of agreement	0.89		
P	<0.001		

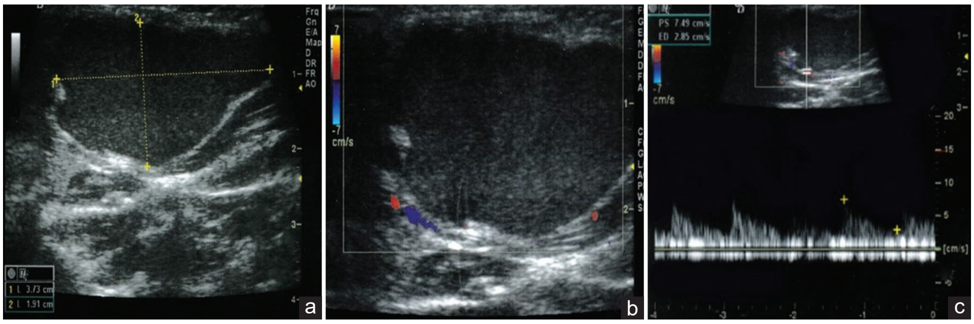
P<0.05.

Figure 1



A 45 year-old female with right index finger soft tissue mass lesion. (a) Gray scale examination revealed well-defined hypoechoic and solid homogeneous lesion, (b and c) CDUS revealed multiple (>3) centrally and peripherally afferent vessels, (d) SDUS of the afferent vessels revealed PSV of 15 cm/s, EDV of 5 cm/s, and an RI of 0.67. The DUS diagnosis was neurofibroma. Histopathological examination after US-guided Tru-Cut needle biopsy revealed neurofibroma. CDUS, color Doppler US; DUS, Doppler ultrasound; EDV, end-diastolic velocity; PSV, peak systolic velocity; SDUS, spectral Doppler US.

Figure 2



Eight year-old male with right cheek swelling: (a) Gray scale assessment revealed well-defined, hypoechoic, and solid homogeneous lesion. (b) CDUS revealed two afferent vessels at the periphery of the lesion. (c) PDUS showed a PSV of 7.5 cm/s while the EDV was 2.8 cm/s giving an RI of about 0.63. The DUS diagnosis of the lesion was adenoma of the parotid gland. Histopathological examination reported pleomorphic adenoma. CDUS, color Doppler US; DUS, Doppler ultrasound; EDV, end-diastolic velocity; PSV, peak systolic velocity.

Table 5 Accuracy of Doppler ultrasound in characterizing the nature of superficial soft tissue lesions

Indices	Value (%)
Sensitivity	89.7
Specificity	83.3
Positive predictive value	97
Negative predictive value	100
Accuracy	97.5
Area under curve	0.92
P	<0.001

P<0.05.

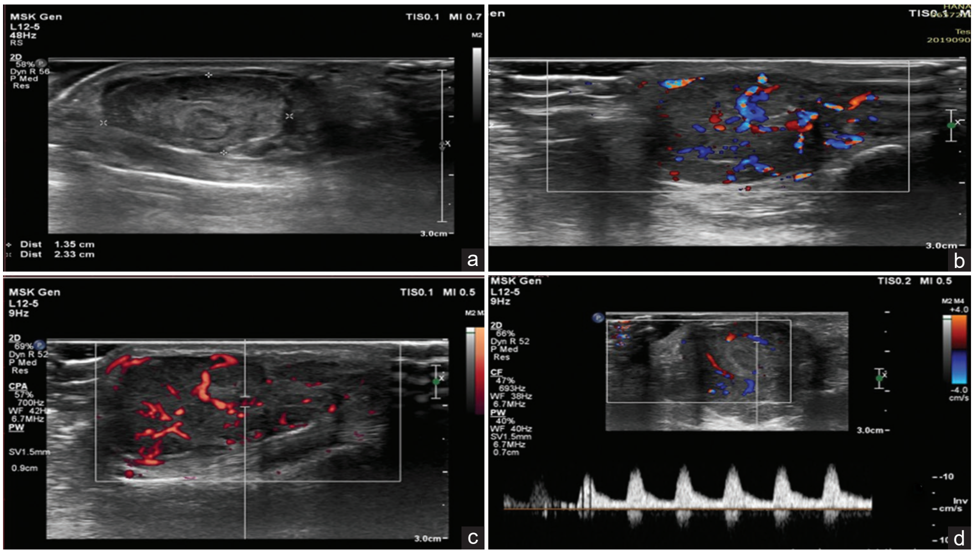
metastatic deposit in the iliac bone, backer cyst, serous collection, pleomorphic adenoma, osteogenic sarcoma, spinal meningocele, Morel-Lavalle's lesion, inflammatory granulation tissue and fibroma of the tendon sheath, cellulitis, and cavernous lymphangioma with a strong agreement ($K = 0.89$) between DUS diagnosis and histopathological results. These results go in concordance also with Hung *et al.* [16].

Table 6 Accuracy of peak systolic velocity, end-diastolic velocity, and resistivity index in the differentiation between pathologically proved benign and malignant lesions

Indices	PSV (cm/s) (%)	EDV (cm/s) (%)	RI (%)
Sensitivity	80	80	27
Specificity	67	83.3	100
Positive predictive value	86	92.3	100
Negative predictive value	57	62.5	35.3
Accuracy	71.4	81	81
Cutoff point	>15	>6.4	>0.72
Area under curve	0.62	0.76	0.50
P	<0.001	<0.001	<0.001

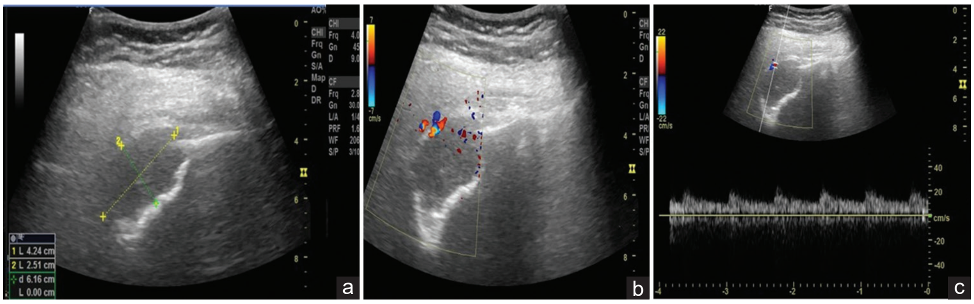
EDV, end-diastolic velocity; PSV, peak systolic velocity; RI, resistivity index. *P*<0.05 was significant.

Figure 3



A 42-year-old female patient with back swelling. (a and b) Gray scale evaluation revealed a well-defined cystic hypoechoic lesion. Heterogeneous with multiple echogenic debris. (c) CDUS demonstrated a single peripheral afferent and two central vessels. (d) SDUS revealed a PSV of about 10 cm/s, EDV of 3 cm/s with RI 0.7. DUS criteria were impressive of a paraspinal abscess. The histopathological report shows inflammatory infiltrate with abundant neutrophils and necrotic debris. CDUS, color Doppler US; DUS, Doppler ultrasound; EDV, end-diastolic velocity; PSV, peak systolic velocity; SDUS, spectral Doppler US.

Figure 4



A 50 year-old female patient with left shoulder swelling. (a) Gray scale evaluation revealed solid hypoechoic lesion. The lesion was irregular, homogeneous, and speculated. (b) In CDUS, there were peripheral and central afferent vessels. (c) In SDUS, the peripheral vessels showed PSV of 32 cm/s, EDV of 8 cm/s, and the RI was 0.75. DUS was suggestive of malignancy featuring a bone tumor (mostly osteosarcoma). Histopathological examination was highly impressive of para-osteal osteosarcoma. CDUS, color Doppler US; DUS, Doppler ultrasound; EDV, end-diastolic velocity; PSV, peak systolic velocity; SDUS, spectral Doppler US.

In the current study, acute or chronic subcutaneous hematomas were detected in about 15% of cases, and the sensitivity of the DUS in detecting these lesions was 100%. Similar results were reported by Ryu *et al.* [17]. A previous study conducted by Tsai *et al.* [18] concluded that US might encounter difficulty in the discrimination between neurofibroma and schwannoma because they share nearly the same sonographic criteria. In spite of this difficulty, DUS examination of the current study showed 100% accuracy in the diagnosis and characterization of both lesions as confirmed by histopathology.

The present work is in agreement with Chiou *et al.* [2] in defining the typical characteristics of lipoma, abscesses, and cystic sebaceous lesions where all cases were correctly diagnosed with an accuracy of 100%, which reflects that a lipoma, cystic sebaceous lesions, and abscesses should not be misdiagnosed when using DUS. These results are also in consistence with Chiou *et al.* [2] in clarifying the reliability of DUS in distinguishing superficial abscesses from other superficial lesions. Although, only one case of cellulitis was included, our study agrees with Evans [19] in recognizing its characteristic sonographic features, and this case was correctly diagnosed by DUS.

Parotid gland pleomorphic adenoma was histopathologically proved in only one case of the current study population, and was correctly spotted with DUS. This result agrees with Angang *et al.* [20] However, Kriss and Desai [21] found that DUS had limitations in certain aspects related to spinal dysraphism such as a small lipoma within the filum, thickened filum with normal cord length, or small dermal sinus tracts. As regards foreign body granuloma, one case was detected in our study, and it was caused by metal chips in the back. During DUS evaluation, the lesion was hypoechoic, heterogeneous, and avascular with a hyperechoic foreign body, showing posterior acoustic shadowing, seen inside. In their study, Ando *et al.* [22] had recommended the use of US for patients with a history of antecedent skin-penetrating trauma.

The current results agree with Shahidi *et al.* [23] in recognizing and describing the DUS characteristics of malignant superficial soft tissue lesions. In the present study, parosteal osteosarcoma, osteogenic sarcoma, and metastatic lesions were correctly characterized with 75% sensitivity, as these lesions infiltrated the nearby muscles and subcutaneous tissue causing an ill-defined border with speculated margins and were hypoechoic with heterogeneous echo texture giving 'sun-ray appearance,' 'sunburst,' or 'hair-on-end' criteria.

By stating that the CDUS features were not significantly different between benign and malignant lesions, our results are in agreement with multiple previous studies [24,25], which found that the presence of vascularity was not very discriminative between benignancy and malignancy and that the color flow could be detected in both benign and malignant lesions. In a result concordant to that of Tsai *et al.* [18], all neurofibromas and schwannomas included in the present study showed high vascularity with multiple afferent vessels. However, Toprak *et al.* [3] reported the low vascularity of these benign tumors.

In their research, Bodner *et al.* [7] stated that PDUS evaluation and spectral analysis of the vascular architecture of musculoskeletal tumors with calculation of the PSV, EDV, and RI can provide additional information about the nature of lesions especially the malignant ones. The above-mentioned results were confirmed by our data, which observed significantly higher spectral Doppler parameters in malignant lesions compared with benign lesions. In addition, the current results revealed that PSV more than 15 cm/s, EDV more than 6.4 cm/s, and RI more than 7.2 were the optimal cutoff points for the discrimination between benign and malignant lesions. Similar values were recorded by two former studies [26,27].

The current study has some limitations. First, the small sample size. Second, US examination is mainly operator dependent and requires long experience. Third, the vascularity of the lesion may change during the different phases of tumor growth. As tumor growth progresses, areas of hypoxia and necrosis occur and thus the vascular pattern of the lesion changes during color Doppler imaging. Finally, as emphasized by Burns and Jaffe [28], the ability of the DUS is limited in assessing the extension of soft tissue lesions when located adjacent to bony structures.

In conclusion, DUS is a real-time noninvasive imaging modality that can be used as an adjunct to the clinical assessment to characterize the nature of various superficial soft tissue lesions. SDUS parameters can discriminate benign from malignant superficial soft tissue lesions, but gray scale and CDUS features cannot.

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Conflicts of interest
None declared.

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