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The Role of Shear Wave Elastography In Diagnosis of Soft Tissue Tumours

H. U. OGUR[1], C. PARLATAN[2], F. SEYFETTINOGLU[1], H. CICEK[1], H. USLU[1], O. CICEK[1]

[1]*Adana City Training and Research Hospital, Orthopaedics and Traumatology, Adana, Turkey;* [2]*Adana City Training and Research Hospital. Radiology, Adana, Turkey.*

Correspondence at: Hasan Ulas Ogur, Adana City Training and Research Hospital, Orthopaedics and Traumatology Department, Serinevler mah. Ege Bagtur Bulvarı, Adana, Turkey. Gsm: +90 505 5272392 - Fax :+90 322 3550155 - E-mail:hasanulas@yahoo.com

ABSTRACT

To obtain more information about the characteristics and stiffness of soft tissue tumors using shear wave elastography (SWE) and magnetic resonance imaging (MRI). This study involved 83 patients diagnosed with a soft tissue mass who underwent surgical excision. These patients were evaluated with MRI and then ultrasonographically and SWE values were measured. The values obtained were compared with the pathology results of the patients following surgical excision. Correlations between SWE and tumour size, grade, and content components were investigated.A total of 52 benign and 31 malignant soft tissue tumors were diagnosed pathologically. The SWE values measured were significantly higher in the malignant and high grade tumors (pswe=11.2) compared with the benign tumors (pswe=3.07) ($p<0.001$). A significant correlation was determined between the SWE values and the fibrotic component in the content of the excised tumour (Spearman correlation: $r=0.571$; $p<0.001$). High SWE values were obtained, close to malignant values in desmoid tumors and those with a dense fibrotic component, despite being benign. The study results showed that high SWE values were associated with the mass content and malignancy in certain tumors. Positive correlations were observed between SWE values and tumor size, grade, and fibrotic component density. When SWE is combined with MRI and ultrasonography, the awareness of benign lesions is increased and may reduce the need for biopsy in benign lesions.

Keywords: Tumor, lesion stiffness, USG, shear wave elastography.

INTRODUCTION

Soft tissue tumors are uncommon, with about 90% being benign. Soft tissue sarcomas account for less than 1% of all malignant tumors[1,2]. Conventional ultrasonography (USG) has high sensitivity in the diagnosis of soft tissue tumors, allowing the specific diagnosis of some benign lesions with information about localisation, solid or cystic form, and vascularity and compressibility (density)[3]. However, this method may not provide sufficient information about tissue hardness. Elastography, which is a technique that has been developed from ultrasound, provides information about tissue hardness. There are two main techniques, strain elastography (SE) and shear wave elastography (SWE). In strain or compression elastography, force is applied to the tissues from the transducer with repeated manual pressure and the displacement (strain) is calculated from the rate at which the tissues return over time. The disadvantages of this method are that results are semi-quantitative and practitioner dependent[4]. In SWE, by applying vibration to tissues through a focused acoustic radiation force impulse (ARFI), values are obtained expressing transverse shear waves (m/sec) and hardness (kp), the velocity of which can then be measured in tissues. This technique generates a colour-coded map illustrating the elastic properties of tissues[4,5]. Consequently, it is considered a valuable preliminary tool for assessing tumor hardness and characteristics. These diagnostic benefits have, in certain cases, reduced the need for biopsy[6].

The aim of this study was to determine the role of SWE in the differentiation of benign and malignant soft tissue tumor characteristics. SWE values vary depending on mass composition. In addition to previous studies, we evaluated various components of mass composition along with the pathologic diagnosis. We also aimed to investigate the relationship between tumor grade and SWE.

MATERIAL AND METHOD

Approval for this retrospective study was granted by the Ethics Committee of Adana City Hospital (Decision no:

2877, Date:12.10.2023). From a total of 98 patients who presented at the orthopedics outpatient clinics between May 2019 and April 2022 with a soft tissue mass of suspected malignancy, 83 were included in the study. All patients underwent MRI,USG, and SWE prior to biopsy. After imaging evaluation, patients underwent biopsy and subsequently surgical excision. The tumors' locations were specified, but they were not classified according to their location. The cases were consecutive These patients comprised 42 females and 41 males with a mean age of 44.36 years and mean follow-up of 1 year (Table I). All these patients underwent magnetic resonace imaging (MRI) and USG, the SWE values were obtained (Figure 1), and the pathology results of excised masses were evaluated (52 benign and 31 malignant tumors). Patients with incomplete imaging data, absence of a pathologic diagnosis, or lack of 1-year follow-up were excluded.

Elastography measurements were taken of the lesions of all patients using the ultrasound device in our clinic (Philips EPIQ 7) using a 1-5 MHz high-resolution convex probe (Philips Health Care, Bothell, WA, USA). For the SWE measurements to be taken of the lesions, the region of interest (ROI) window was formed as a rectangle including the target point reflecting the basic characteristics of the lesion, from the most solid component as centrally in the mass as possible and not including vascular tissue and necrotic calcific areas with US criteria (Figure 2). The measurements were taken in the axial and sagittal plane in the same location and the mean values were obtained in kPa and m/s units. All the measurements were taken by a single radiologist with USG experience. Measurements were obtained by making three different measurements for the central point of the solid component of each lesion and averaging the values. In patients with metastatic disease or hematologic malignancies presenting with multiple focal mass lesions, the mean SWE value obtained from the different lesions was calculated. The ROI dimensions we used during the process could not be changed by the user and had a fixed measurement area determined by the device. ROIs were rectangular in shape and applied to an area of 1 cm2. The SWE technique used in the device could examine lesions up to 8 cm deep from the skin.To ensure standardized and reliable measurements and to minimize erroneous data, lesions smaller than twice the ROI area were excluded from the study. The data obtained were

Table I. — Histopathological Diagnosis of Tumors and pSWE Values (kPa).

Pathological diagnosis (Benign, n=52)	pSWE (kPa, mean ± SD)	Pathological diagnosis (Malignant, n=31)	pSWE (kPa, mean ± SD)
Lipoma (5)	2.48 ± 0.40	Undifferentiated pleomorphic sarcoma (5)	13.3 ± 3.0
Elastofibroma dorsi (6)	12.34 ± 2.10	Myxoid liposarcoma (4)	5.68 ± 0.92
Desmoid fibromatosis (3)	13.25 ± 2.42	Well-differentiated liposarcoma (4)	4.53 ± 0.63
Schwannoma (6)	5.90 ± 1.30	Synovial sarcoma (3)	15.3 ± 1.60
Neurofibroma (4)	4.03 ± 1.20	Myxofibrosarcoma (2)	14.51 ± 1.80
Hemangioma (4)	2.3 ± 0.60	Dermatofibrosarcoma (1)	36.83 ± 2.20
Vascular malformation (3)	2.7 ± 0.40	Leiomyosarcoma (2)	13.80 ± 1.60
Epidermal cyst (2)	6.66 ± 0.91	Fibrosarcoma (1)	5.50 ± 1.10
GCT tendon sheath (2)	2.6 ± 0.50	Renal cell carcinoma metastasis (2)	9.36 ± 1.10
Myxoma (1)	29.84 ± 3.10	B-cell lymphoma (1)	30.54 ± 3.10
Ganglion cyst (1)	3.33 ± 0.10	Malignant eccrine poroma (1)	22.62 ± 9.60
Trichilemmal cyst (1)	13.40 ± 1.10	Osteosarcoma (1)	11.30 ± 2.90
Lymphadenopathy (2)	2.03 ± 0.46	Chondrosarcoma (1)	26.6 ± 2.60
Dermatofibroma (2)	22.40 ± 2.10	MPNST (1)	5.91 ± 1.0
Myositis ossificans (2)	12.67 ± 1.30	Malignant melanoma (1)	4.36 ± 0.90
Lipoblastoma (2)	2.40 ± 0.30	Thyroid carcinoma metastasis (1)	4.48 ± 0.90
Atypical lipomatous tumor (3)	4.66 ± 1.06		
Leiomyoma (1)	3.21 ± 0.87		
Organized hematoma (1)	1.92 ± 0.49		
Fibrolipoma (1)	1.19 ± 0.34		

MPNST:Malignant Peripheral Nerve Sheath Tumor; All pSWE values are expressed in kilopascals (kPa).

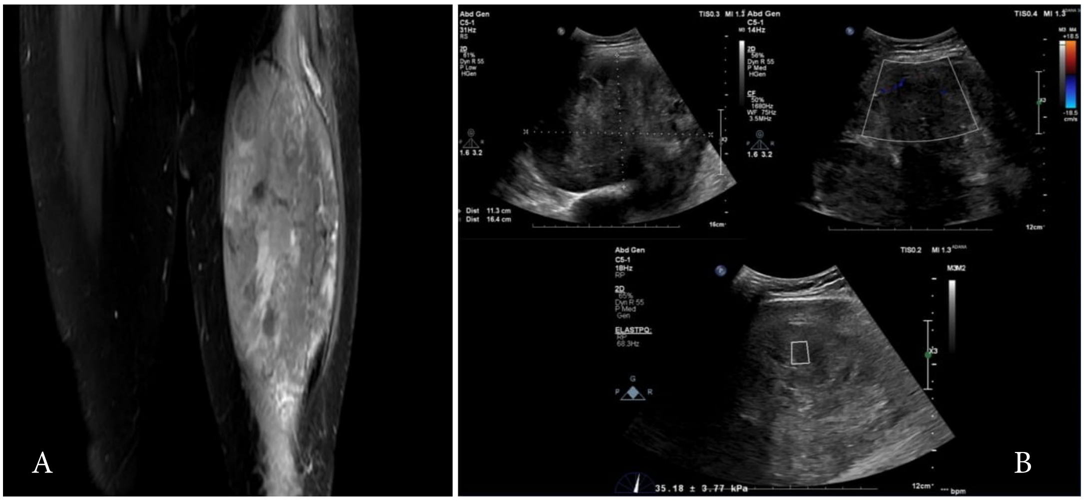

Fig. 1 — A. A heterogeneous hypoechoic mass lesion located between the muscle planes in the anterior thigh, measuring 11.3x16.4 cm in size. Coronal postcontrast MRI images of the lesion located between the muscle planes on the front of the thigh in a patient diagnosed with undifferentiated pleomorfic sarcoma . B. The lesion has a heterogeneous internal structure with millimetric cystic necrotic areas and a dense solid component with vascularization observed. Average values of 35.18+/-3.77 kPa were obtained in elastography measurements made for the area closest to the center of the lesion and where the solid component is most dense.

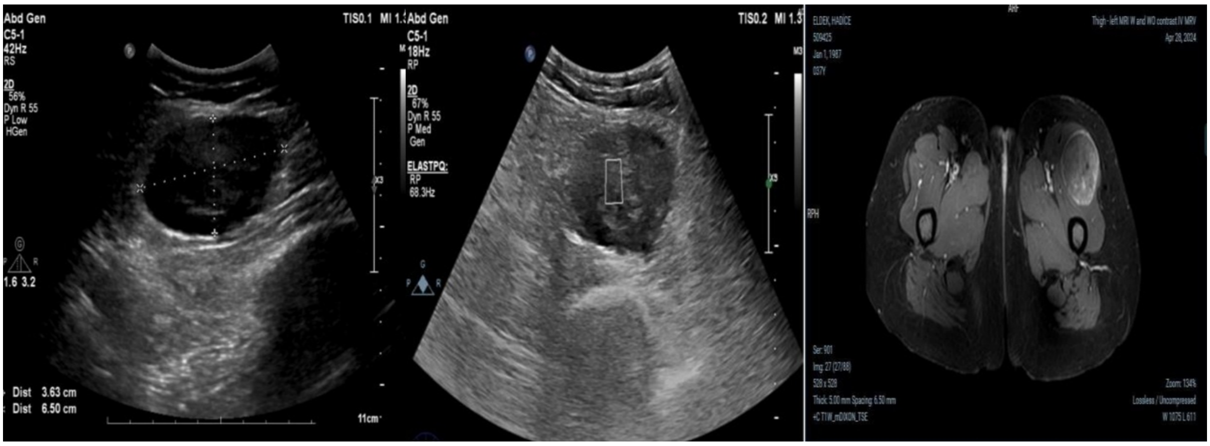

Fig. 2 — A. A heterogeneous hypoechoic mass lesion located between the muscle planes in the anterior thigh, measuring 3.6x6.5 cm in size, with no obvious vascularization B. The lesion stiffness of a patient with intramusculer mixoma was measured as 24.18+/-2.27kPa by elastography C. Axial postcontrast MRI images of the lesion located between the muscle planes on the front of the thigh.

analyzed statistically using SPSS Ver. 23 software. Conformity of the data to normal distribution was examined using the Shapiro-Wilk and Kolmogorov-Smirnov tests. In the comparisons of the categorical variables of the groups, Yates's corrected test and the Fisher-Freeman-Halton test were used. Relationships between non-normally distributed data were examined using Spearman's rho correlation coefficient.

RESULTS

The distribution of masses was as follows: 24 located in the upper extremity, 40 in the lower extremity, and 19 in the trunk. The distribution of histologic grades of the patients with a malignant mass was determined as 19.4% grade 1, 35.5% grade 2, and 45.2% grade 3. The SWE values and components of the mass content were determined (Table II). The SWE values and the size of the mass in malignant tumors were statistically significantly higher and the rate of lipomatous component was lower compared with benign tumors ($p<0.001$) (Table II). High SWE values were obtained in fibrotic and desmoid tumors despite being benign (Figure 2). Low SWE values were observed in malignant low-grade liposarcomas. The mean size was determined as 4 x 2.5 cm for benign masses and 10 x 7 cm for malignant masses, and the difference was statistically significant ($p<0.001$) (Table II). Receiver

Table II. — Comparisons of quantitative parameters of the tumors.

	Benign(n=52)	Malignant(n=31)	Total(n=83) %95CI	Test statistic	p
Gender Female Male	 32(76.2%) 20 (48.8%)	 10(23.8%) 21 (51.2%)	 42(50.6%) 41 (49.4%)	χ^2 = 5.542	 0.019
Age (years)	41.0(18-82)	50.0 (19-78)	44.0(18-82) *	Z=-2.246	0.028
pSWE (kpa)	3.07 (0.34 - 29.84)	11.2 (1.26 - 36.83)	4.91 (0.34 - 36.83)	U=423.0	<0.001
MaximumTumor diameter(cm)	4.0 (1.6 – 13.0)	10.0 (3.5 – 120.0)	6.0 (1.6 – 120.0)	U=179.5	<0.001
Tumour width(cm)	2.5 (1.0 – 9.0)	7.0(2.0 – 60.0)	4 (1.0 – 60.0)	U=134.5	<0.001
Fibrotic component(%)	39.41 ± 25.24	48.33 ± 26.46	44 ± 25.89 *	Z=-1.020	0.315
Lipomatous component(%)	85 (30 - 95)	45 (10 - 90)	75 (10 - 95)	U=29.5	0.016

^xIndependent Paired Samples t-test; ^y Mann-Whitney U test, mean± standard deviation, median (minimum – maximum) values. *%95Confidence interval. Continuous variables are presented as median(minimum-maximum)Categorical variables are presented as number (percentage). Continuous variables are presented as median (minimum–maximum) values due to non-normal distribution. Shear wave elastography values are expressed in kilopascals (kPa). Group comparisons were performed using the chi-square test for categorical variables and the Mann–Whitney U test for continuous variables.

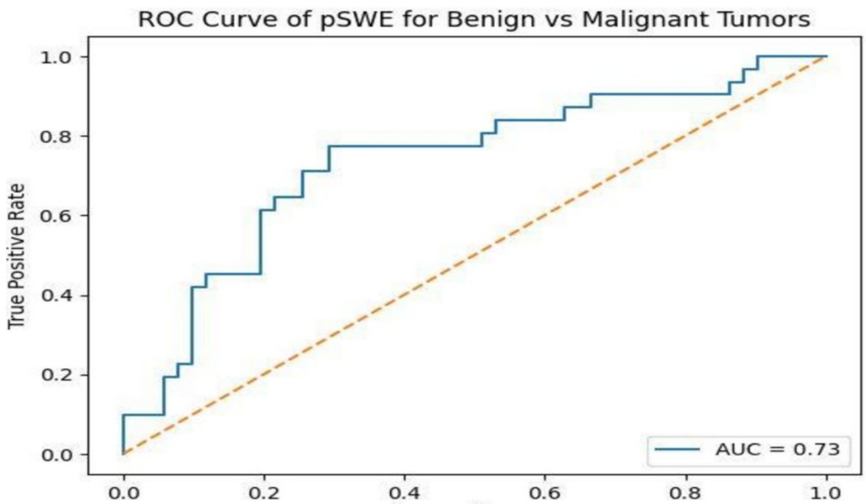

Fig. 3 — Receiver operating characteristic (ROC) curve demonstrating the diagnostic performance of point shear wave elastography (pSWE) for differentiating benign and malignant soft tissue tumors. The area under the curve (AUC) was 0.73, indicating moderate discriminative ability.

operating characteristic (ROC) curve analysis was performed to evaluate the diagnostic performance of pSWE in differentiating benign and malignant soft tissue tumors. The area under the curve (AUC) was 0.73, indicating a moderate-to-good discriminative ability of pSWE. These findings suggest that higher pSWE values are associated with malignancy; however, partial overlap exists between benign and malignant lesions (Figure 3).

The relationship between the SWE values and histologic grades was examined in patients with malignant tumor diagnoses (Table III). There was no statistically significant differences between grade 1 and grade 2 tumors, but there was a statistically significant difference between grade 1 and grade 3 tumors. There was a statistically significant difference between grade 2 and grade 3 tumors. Regression analysis was conducted to evaluate the independent effects of tumor characteristics on SWE values (Table IV). To enhance the reproducibility of our single-examiner study, the intra-observer reliability of SWE measurements was assessed. For this purpose, 20 randomly selected lesions were re-measured by the same examiner in a separate session under identical conditions (Table V).

DISCUSSION

Although soft tissue sarcomas constitute <1% of all malignant tumors, soft tissue masses may be

Table III. — Comparisons of pSWE (elasto) values according to histological grade (with 95% CI).

Histological Grade	n	pSWE(kPa)	Median (min–max)	p
Grade 1	6	4.67	(2.34–17.51) a	0.006
Grade 2	11	6.63	(1.26–26.68) a	
Grade 3	14	19.79	(5.5–36.83) b	

^x Kruskall Wallis H Test; ^(a-b) no difference between groups with the same letter (there were diferences betwen grade1 and 3 and 2 and 3); pSWE values are expressed in kilopascals (kPa) and presented as median (minimum–maximum) values. Group comparisons were performed using the Kruskal–Wallis test.

Table IV. — Regression Analysis.

Predictor	B (unstandardized)	SE	t	p	Standardized β	Partial r	VIF
Largest diameter (cm)	-0.008	0.481	-0.017	0.987	-0.004	-0.004	5.93
Second diameter (cm)	0.086	0.193	0.447	0.660	0.104	0.105	2.52
Fibrotic component (%)	0.081	0.067	1.198	0.246	0.246	0.272	1.27
Lipomatous component (%)	0.008	0.099	0.084	0.934	0.020	0.020	1.07
Histologic grade	6.625	3.373	1.964	0.065	0.490	0.420	4.90

Model statistics: $R^2 = 0.301$; adjusted $R^2 = 0.107$; $F(5,18) = 1.55$; $p = 0.225$.
pSWE values expressed in kilopascals (kPa) were used as the dependent variable. Regression analysis was performed only in malignant tumors and should be considered exploratory due to the limited sample size and heterogeneity of tumor subtypes. Variance inflation factors (VIF) below 6 indicated no problematic multicollinearity among predictors.

Table V.

Analysis	Value	95%CI	Comment
İntra- observer ICC(3,1)	0.92	0.86-0.97	Excellent reliability
CV(%)	6,4%	-	High measurement precision

ICC: intraclass correlation coefficient; CV: coefficient of variation.
ICC(3,1) model (two-way mixed effects, absolute agreement) was used for repeated pSWE measurements obtained by a single examiner. pSWE values are expressed in kilopascals (kPa)
To reinforce the reproducibility of our single-examiner measurements, 20 randomly selected lesions were re-measured in a separate session. Intra-observer reproducibility analysis demonstrated excellent reliability (ICC = 0.92; 95% CI: 0.86–0.97).
Measurement precision was high, with a CV of 6.4%.

frequently encountered. As imaging methods in the diagnosis of soft tissue tumors, MRI and USG are used most often, and pathologic sampling is usually performed for a definitive diagnosis. On conventional USG, pathologic and healthy tissues can sometimes show similar echogenity in early-stage diseases. With sonoelastographic techniques, which are newer modalities of conventional USG, it has become possible to obtain additional information related to the elastic properties, hardness, and characteristics of soft tissue[7,8].

The aim of this study was to evaluate the advantages of sonoelastography in diagnosis and treatment by correlating USG, MRI, and SWE values with the histologic diagnosis. In general, while USG and Doppler USG are useful in distinguishing benign from malignant tumors, sonoelastography has not shown a significant difference in tumour hardness[9,10]. Soft tissue tumors comprise a variety of histologic components, including calcification, fibrotic changes, and regions of hemorrhage, necrosis, and cystic degeneration[11]. The results of the current study showed signficant differences between benign and malignant tumors in respect of the SWE values. The reason for the greater hardness and higher SWE values in malignant tumors is that the measurements were taken from the most solid part of the tumor outside necrotic areas. In masses where there was more fibrotic material in the solid component, the SWE values were seen to be higher.

In previous studies using combined visual examinations and quantitative methods such as SWE, it has been seen that invasive proceduree such as biopsies can be avoided by obtaining stronger evidence that lesions are benign, as has been reported in breast radiology[12,13]. Taware et al. reported that SWE could increase the accuracy of soft tissue lesion diagnosis together with USG, but because diagnostic accuracy is affected by patient age, there is no single cut-off point that can be applied universally[14]. Öztürk et al. stated that USG could differentiate benign and malignant tumors and SWE made no contribution in the differentiation of these tumors[9]. Although statistically significantly high SWE values were obtained in malignant tumors in the current study, similar values were also obtained in some benign masses. Although it was concluded that a diagnosis of malignancy could not be made according to these values alone, they could be considered to be helpful in respect of the hardness and content of the mass and in the grading of malignant masses. In patients who have previously been diagnosed as having fibrous tumors or those with systemic disease such as neurofibromatosis, observation without biopsy may be recommended with MRI support, despite high SWE values.

Frey et al. reported that malignant tumors were more invasive to adjacent tissues than benign tumors and had lower elasticity[15]. In contrast, based on this histologic background, Hahn et al. determined that malignant soft tissue tumors had lower strain ratios (qualitative) and higher elasticity scores than benign soft tissue tumors[11]. In studies by Winn et al. in which 148 soft tissue lesions were evaluated using USG and SWE, no significant differences were reported in the SWE values between benign and malignant lesions[4]. In the current study, the hardness and elasticity values were obtained with SWE, which is a quantitative technique. These values were found to be statistically significantly higher in the malignant masses.

Several studies using SE found that deeper lesions tended to be firmer[16,17]. In other research, higher SWE values were associated with malignancy in subcutaneous lesions rather than lesions with a deep location.14 As in previous literature, some findings of the current study, such as a large lesion, irregular borders, and increased vascularity, were confirmed as strong markers of malignancy[2,18-20].

Differentiation with imaging may be difficult between atypical lipomatous tumors and benign simple lipomas, and even in well-differentiated liposarcomas[21,22]. In parallel with the study by Winn et al., differentiation between these masses in the current study was seen to be able to be made using shear wave velocities, especially in malignant tissues[4]. Shear waves cannot be obtained in areas of cystic degeneration/necrosis and areas where there are fluid pockets[23]. Therefore, in our study, elastographic measurements were obtained from the most solid and viable portion of the mass. In other research conducted at our hospital using the same device for different organs, elastography values comparable to those in our study were reported[24,25]. Although malignant masses showed high SWE values regardless of location in this study, these values were not used as definitive diagnostic criteria because some benign masses, especially those with substantial fibrosis, also exhibited high values. However, if there is an MRI-supported benign fibrous tumour image following high SWE values, additional investigations and some surgical interventions may be avoided, or less radical interventions may be preferred during surgery.

However, by obtaining an idea about hardness and elasticity, it can be considered that patients will be spared unnecessary interventions and costs by avoiding biopsies of benign lesions. As has been stated in previous studies of large series, the use of ultrasound elastography together with B-mode ultrasound seems to be a good complementary tool. It has been reported that this technique is reliable and repeatable, strengthens the evaluation of malignant lesions in the musculoskeletal system, can be used to increase diagnostic reliability, and is a method that can be further developed[10,16,19].

As reported by Taware et al., SWE in combination with USG may improve the diagnostic accuracy of soft tissue lesion but cannot be defined by a single universal cut-off value[14]. We concluded that there was no definitive cut-off value to distinguish between benign (kpa=0.3-29.7) and malignant (kpa=1.27-36.4) lesions and that high kpa values could be obtained in tumors with less fat and more fibrotic component or high grade. Hybrid techniques combining visual inspection and quantitative methods such as SWE may provide additional confidence that a lesion is benign, and more invasive measures such as biopsy can be avoided as shown in breast radiology[6,13,14]. Similar MRI findings and SWE values, as observed in our study, may also be seen in atypical lipomatous tumors and lipomas. Clinical observation may be recommended for lesions that have been present for a long period and show no evidence of growth. However, if prominent septa are identified on MRI or if partially elevated SWE values are detected in different regions of the lession, we believe physicians should exercise caution regarding the possibility of well-differentiated liposarcomas. Although SWE may provide an indication of tissue stiffness, a definitive diagnosis must always be established through histopathologic examination. In such cases, preparation for extensive surgery following biopsy, along with additional diagnostic investigations, may be necessary. Although pSWE demonstrated acceptable diagnostic performance, overlap between benign fibrotic lesions and malignant tumors limited its discriminatory power. Therefore, pSWE should be interpreted in conjunction with conventional ultrasound findings and clinical features rather than as a standalone diagnostic tool.

Further research is warranted; however, this study may serve as a valuable reference for future investigations by providing SWE data in relation to mass content determined through histologic grading and histopathologic analysis.

Limitations

The study included a relatively small patient population, indicating that further research involving larger cohorts is necessary to validate these results. The smaller range and number of malignant tumors than benign masses could be seen as a limitation. There is considerable variability among malignant tumors of the same type included in this study, particularly regarding their grade and histopathologic subtype. This diversity makes it challenging to generalise findings related to hardness and SWE values, which represents one of the study's limitations.

CONCLUSION

In summary, SWE does not independently predict outcomes but can offer valuable supplementary information during assessments where USG serves as an additional imaging tool. Beyond evaluating the appearance of tumoral lesions, particularly with MRI, SWE can provide cautionary insights regarding lesion grade, stiffness, and other distinguishing characteristics. The intensity of interventional procedures can be reduced, especially in benign lesions. Nevertheless, there is a need for further research into the role of SWE in lesion classification.

Conflict of Interest: On behalf of all authors, the corresponding author states that there is no conflict of interest.

All authors read and approved the final version of the manuscript.

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