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Original Research Article

Role of Ultrasound Shear-Wave Elastography in the Evaluation and Characterization of Focal Liver Lesions: A Prospective Observational Study

Vaibhav Mehta

Assistant Professor, Department of Radiology, GMERS Medical College & Hospital, Vadnagar

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Corresponding author: Dr. Vaibhav Mehta

Conflict of interest: Nil

Abstract

Background: Focal liver lesions (FLLs) are frequently detected on abdominal ultrasonography and include a wide spectrum of benign and malignant lesions. Although conventional B-mode ultrasonography and color Doppler provide valuable morphological and vascular information, characterization of some FLLs remains challenging because of overlapping imaging features. Shear-wave elastography (SWE) provides quantitative assessment of tissue stiffness and may provide additional information for lesion characterization. This study evaluated the role of SWE in the characterization of FLLs and its potential utility in differentiating benign from malignant lesions.

Methods: This prospective observational study was conducted at Smt. N.H.L. Municipal Medical College and S.V.P. Hospital between August 2018 to April 2020. Fifty patients with focal liver lesions were included. The study population comprised 30 males and 20 females, aged 21–78 years. All patients underwent B-mode ultrasonography and color Doppler examination followed by SWE using a Mindray Resona 6 ultrasound system. Four stiffness measurements were obtained from different portions of each lesion, and two measurements were obtained from the adjacent hepatic parenchyma. Stiffness values were recorded in kilopascals (kPa). Final diagnosis was established by contrast-enhanced computed tomography and/or histopathological examination, as clinically indicated.

Results: Among the 50 patients, 20 had benign and 30 had malignant focal liver lesions. Hemangioma was the most common benign lesion, whereas metastasis was the most common malignant lesion. The mean SWE values were 9.6 kPa for hepatic adenoma, 10.1 kPa for hemangioma, 10.5 kPa for regenerating nodules, and 15.3 kPa for focal nodular hyperplasia. Among malignant lesions, mean SWE values were 16.6 kPa for hepatocellular carcinoma (HCC), 21.5 kPa for metastases, and 52.3 kPa for intrahepatic cholangiocarcinoma. Overall, malignant lesions demonstrated a higher mean SWE value than benign lesions (25.0 vs. 11.1 kPa). In patients with cirrhosis, the mean SWE value was higher for HCC (16.6 kPa) than for regenerating nodules (10.5 kPa).

Conclusion: SWE demonstrated higher tissue stiffness in malignant compared with benign focal liver lesions and may provide useful complementary information during lesion characterization. It also demonstrated a difference in mean stiffness between HCC and regenerating nodules in cirrhotic liver. However, overlap in stiffness values may occur among different lesion types, and measurements may be influenced by lesion composition, background liver disease, acquisition technique, and equipment. Therefore, SWE should be considered an adjunct to conventional ultrasonography and other appropriate imaging modalities rather than a standalone diagnostic technique.

Keywords: Focal Liver Lesions; Shear-Wave Elastography; Ultrasound Elastography; Liver Stiffness; Hepatocellular Carcinoma; Hepatic Metastasis; Hemangioma; Focal Nodular Hyperplasia.

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Introduction

Focal liver lesions (FLLs) are frequently encountered during abdominal ultrasonography and include a wide spectrum of benign and malignant conditions. Common benign lesions include hemangioma, focal nodular hyperplasia (FNH), and hepatocellular adenoma, while malignant lesions include hepatocellular carcinoma (HCC), intrahepatic cholangiocarcinoma (ICC), and metastatic disease. B-mode ultrasonography is commonly used for the initial detection and

characterization of FLLs, providing information regarding lesion size, number, echogenicity, margins, internal architecture, and relationship to adjacent structures. Color Doppler further provides information regarding vascularity. However, considerable overlap in sonographic appearances may make differentiation between benign and malignant lesions difficult, particularly in patients with chronic liver disease or a history of malignancy. Indeterminate FLLs may require further evaluation with contrast-enhanced ultrasound (CEUS), computed tomography (CT), magnetic resonance imaging (MRI), or histopathological examination. Although contrast-enhanced imaging remains central to lesion characterization, elastography may provide additional quantitative information regarding tissue stiffness and should be considered a complementary technique. [1,2]

Shear-wave elastography (SWE) is an ultrasound-based technique that quantitatively assesses tissue stiffness by measuring shear-wave propagation. The development of elastography and acoustic radiation force impulse (ARFI)-based techniques established the basis for quantitative assessment of tissue mechanical properties. [3-5] Differences in stiffness among FLLs may reflect variations in cellularity, fibrosis, stromal composition, vascularity, hemorrhage, and necrosis. Several studies have reported higher stiffness in malignant compared with benign liver lesions. [6-10]

However, overlap in stiffness values between different lesion types remains a limitation. Measurements may also be influenced by the elastography technique, ultrasound system, lesion characteristics, background liver disease, lesion depth, region-of-interest placement, and acquisition protocol. A meta-analysis involving 1,894 liver lesions reported pooled sensitivity and specificity of approximately 82% for differentiating malignant from benign lesions, with an area under the receiver operating characteristic curve of approximately 0.89, but substantial variation in techniques and diagnostic thresholds was observed among studies. [11]

WFUMB guidance has recognized the potential role of elastography in focal liver masses while emphasizing the limitations of available evidence and the importance of standardized acquisition and interpretation. [12,13] Recent studies have also explored the combination of SWE with CEUS, suggesting that multiparametric assessment may improve lesion characterization. [14] Despite these findings, the role of SWE in the characterization of individual types of FLLs and its usefulness in differentiating malignant lesions from benign lesions such as regenerating nodules in cirrhotic liver remain of clinical interest. Therefore, the present study was undertaken to evaluate SWE measurements in different FLLs and assess their potential complementary role in lesion characterization.

Aim: To evaluate the role of ultrasound shear-wave elastography in the evaluation and characterization of focal liver lesions.

Objectives

1. To evaluate the potential role of SWE in differentiating benign from malignant focal liver lesions.
2. To determine and compare the mean SWE values of benign and malignant focal liver lesions.
3. To compare the stiffness of focal liver lesions with that of the surrounding hepatic parenchyma.
4. To assess the potential role of SWE in differentiating hepatocellular carcinoma from regenerating nodules in cirrhotic liver.
5. To assess the complementary role of SWE along with B-mode ultrasonography and color Doppler in the characterization of focal liver lesions.

Materials and Methods

Study Design and Setting: This prospective observational study was conducted in the Department of Radiology of Smt. N.H.L. Municipal Medical College and S.V.P. Hospital, Gujarat from August 2018 to April 2020. A total of 50 patients with focal liver lesions detected on ultrasonography were included in the study.

Study Population: The study included 50 patients with focal liver lesions. There were 30 males (60%) and 20 females (40%), with an age range of 21–78 years and a mean age of approximately 53 years.

Inclusion and Exclusion Criteria: Patients with a focal liver lesion involving either hepatic lobe identified on ultrasonography were eligible for inclusion. Patients were excluded if they had liver abscess, gross ascites, inadequate cooperation for ultrasound examination, or previous local treatment of the focal liver lesion, including percutaneous ethanol injection, radiofrequency ablation, or transarterial chemoembolization.

Ethical Considerations and Clinical Assessment: Written informed consent was obtained from all participants before the examination. Relevant clinical information was recorded, including history of previous malignancy, oral contraceptive use in female patients, alcohol intake, and previous or current jaundice. The study was conducted in accordance with the ethical requirements of the institution.

Ultrasound Examination: Ultrasonography was performed using a Mindray Resona 6 ultrasound

system with convex and linear transducers. Patients were asked to fast for at least 2 hours before examination and rested for approximately 10 minutes before elastography acquisition. The examination was performed with the patient in the supine or approximately 30° left lateral position. The right arm was placed behind the head when required to improve the intercostal acoustic window. Each lesion was initially assessed using B-mode ultrasonography followed by color Doppler examination. The evaluated characteristics included the number, location, size, echogenicity, margins, internal architecture, posterior acoustic features, vascularity, relationship to hepatic and portal veins, associated biliary dilatation, and morphology of the background liver. A provisional diagnosis was made based on conventional ultrasonography and color Doppler findings before SWE assessment.

Shear-Wave Elastography Technique: SWE was performed following B-mode and color Doppler examination using the same Mindray Resona 6 ultrasound system. A region of interest (ROI) measuring approximately 1 × 0.5 cm was placed completely within the focal lesion, avoiding major vessels and biliary structures. In larger or heterogeneous lesions, measurements were obtained from different representative solid portions. When cystic, necrotic, hemorrhagic, or calcified areas were present, the ROI was positioned within the viable solid component whenever feasible.

Four SWE measurements were obtained from different portions of each lesion. Two additional measurements were obtained from the surrounding hepatic parenchyma approximately 2–3 cm from the lesion, avoiding visible vessels and biliary structures. Measurements were obtained during a short breath-hold to minimize respiratory motion. SWE values were recorded in kilopascals (kPa). For statistical analysis, the four measurements obtained from each lesion were averaged to obtain a representative lesion-level SWE value. Similarly, the measurements obtained from the surrounding hepatic parenchyma were averaged to obtain a background liver stiffness value.

Reference Standard and Final Diagnosis: The final diagnosis of the focal liver lesion was established using contrast-enhanced computed tomography (CECT) and/or histopathological examination, according to the clinical circumstances. When histopathological examination was available, the pathological diagnosis was considered definitive. In patients who did not undergo biopsy because it was not clinically indicated, the final diagnosis was based on contrast-enhanced imaging findings together with the available clinical and imaging follow-up.

Statistical Analysis: Data were entered into a structured database and analyzed using appropriate statistical methods. Continuous variables were summarized using mean and standard deviation or median and interquartile range, as appropriate, while categorical variables were expressed as frequencies and percentages. Mean SWE values were compared between benign and malignant focal liver lesions and among individual lesion types. Lesion stiffness was also compared with the stiffness of the surrounding hepatic parenchyma. In patients with cirrhosis, SWE values of hepatocellular carcinoma were compared with those of regenerating nodules. An appropriate statistical test was used according to the distribution and type of data. A two-sided p value <0.05 was considered statistically significant.

Results

Demographic Characteristics

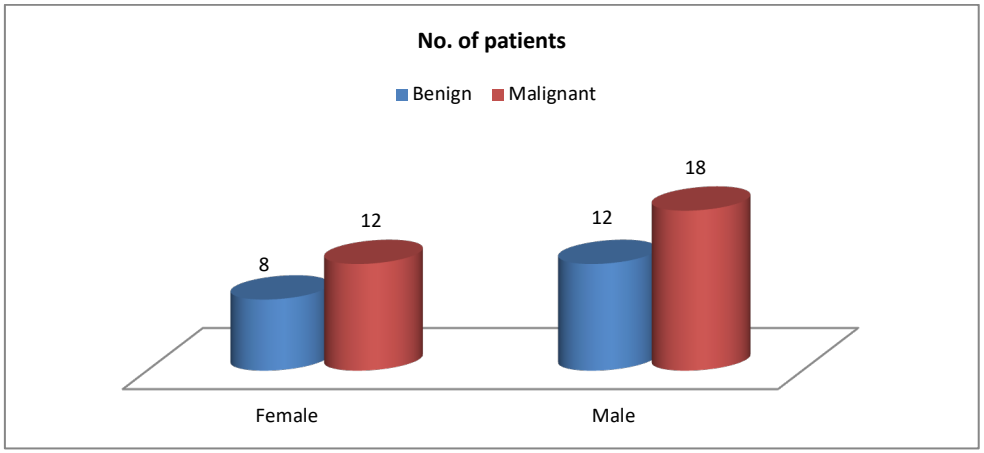

Figure 1: Gender distribution according to benign and malignant focal liver lesions

Fifty patients with focal liver lesions were included in the study. There were 30 males (60%) and 20 females (40%). The age range was 21–78 years, with a reported mean age of approximately 53 years. Among the male patients, 18 (60%) had malignant lesions, while among female patients, 12

(60%) had malignant lesions. Thus, the proportion of malignant lesions was similar among males and females in the study population.

Distribution of Focal Liver Lesions

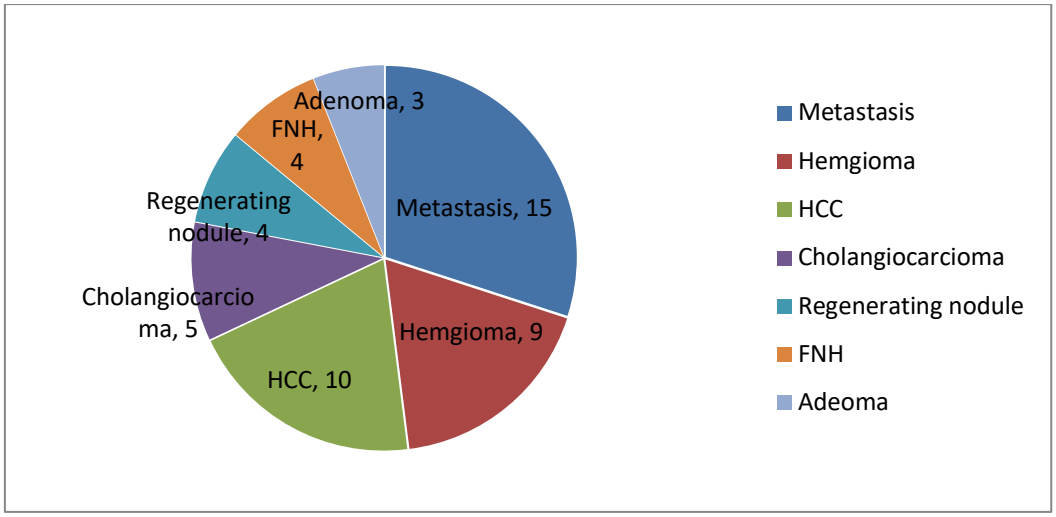

Figure 2: Distribution of focal liver lesions according to final diagnosis

Of the 50 patients included, 20 (40%) had benign focal liver lesions and 30 (60%) had malignant lesions.

The benign diagnostic categories comprised hepatic adenoma, hemangioma, focal nodular hyperplasia, and regenerating nodules. The malignant diagnostic categories comprised hepatocellular carcinoma, metastatic lesions, and intrahepatic cholangiocarcinoma. Hemangioma was the most common benign lesion, accounting for 9 patients (18% of the study population). Metastatic lesions were the most common malignant category, accounting for 15 patients (30%).

Among the 30 patients with malignant lesions, 12 (40%) had a single focal lesion and 18 (60%) had multiple focal lesions. Among the 20 patients with benign lesions, 12 (60%) had a single focal lesion and 8 (40%) had multiple focal lesions.

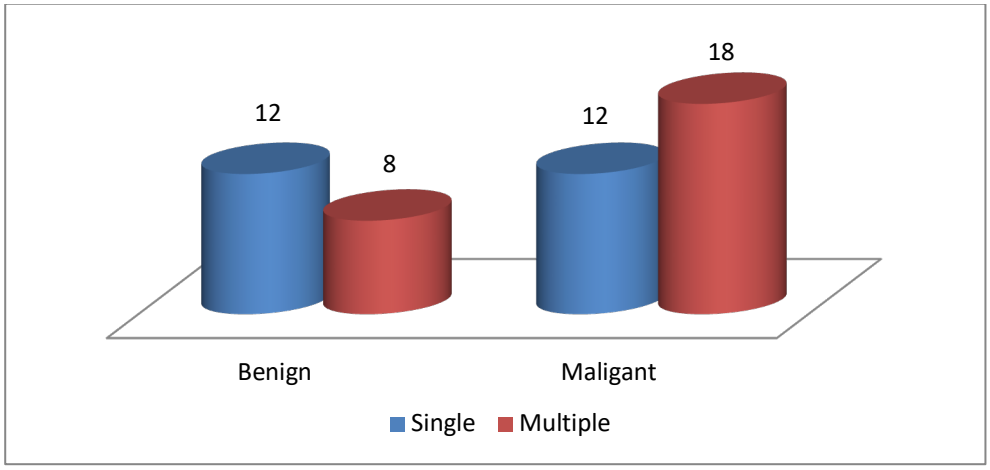

Figure 3: Distribution of patients according to number of focal liver lesions

Table 1: Distribution of focal liver lesions according to final diagnosis

Final diagnosis	Number	Percentage
Hepatic adenoma	3	6%
Hemangioma	9	18%
Focal nodular hyperplasia	4	8%
Regenerating nodule	4	8%
Hepatocellular carcinoma	10	20%
Metastasis	15	30%
Intrahepatic cholangiocarcinoma	5	10%
Total	**50**	**100%**

Mean SWE Values of Benign Lesions

Table 2: Mean SWE values according to final diagnosis

Final diagnosis	Mean SWE (kPa)
Hepatic adenoma	9.6
Hemangioma	10.1
Regenerating nodule	10.5
Focal nodular hyperplasia	15.3
Hepatocellular carcinoma	16.6
Metastasis	21.5
Intrahepatic cholangiocarcinoma	52.3

The reported mean SWE values of the benign lesions were 9.6 kPa for hepatic adenoma, 10.1 kPa for hemangioma, 10.5 kPa for regenerating nodules, and 15.3 kPa for focal nodular hyperplasia.

Among the benign categories, hepatic adenoma demonstrated the lowest reported mean stiffness, whereas FNH demonstrated the highest. Because some diagnostic subgroups contained only three to five patients, these values should be considered descriptive rather than reference values.

Mean SWE Values of Malignant Lesions: Among the malignant lesions, the reported mean SWE values were 16.6 kPa for HCC, 21.5 kPa for metastases, and 52.3 kPa for intrahepatic cholangiocarcinoma. Intrahepatic cholangiocarcinoma demonstrated the highest reported mean stiffness among the malignant categories included in this study.

The relatively high stiffness observed in ICC may be related to the prominent fibrous/desmoplastic stromal component frequently present in this tumor type.

Nevertheless, only five ICC cases were included, and therefore the observed value should not be interpreted as a diagnostic cutoff.

Comparison between Benign and Malignant Lesions

Table 3: Comparison of benign and malignant focal liver lesions

Category	Number	Mean SWE (kPa)
Benign	20	11.1
Malignant	30	25.0

The reported overall mean SWE value was 11.1 kPa for benign lesions and 25.0 kPa for malignant lesions. Thus, malignant lesions demonstrated higher mean stiffness than benign lesions in the present cohort. The observed difference in mean stiffness supports the potential role of SWE as a complementary imaging parameter in the evaluation of focal liver lesions. However, these group means should not be interpreted as diagnostic thresholds. Individual lesion categories demonstrated overlap, and absolute SWE values may be influenced by lesion composition, background liver disease, measurement technique, and ultrasound equipment.

Comparison of Lesion Stiffness with Surrounding Hepatic Parenchyma

Table 4: Comparison of lesion and surrounding hepatic parenchymal stiffness

Diagnosis	Mean parenchymal SWE (kPa)	Mean lesion SWE (kPa)
Hepatic adenoma	8.66	9.6
Hemangioma	9.42	10.1
Regenerating nodule	13.0	10.5
Focal nodular hyperplasia	8.63	15.3
Hepatocellular carcinoma	18.3	16.6
Metastasis	10.0	21.5
Intrahepatic cholangiocarcinoma	10.6	52.3

The mean SWE values of the focal lesions and surrounding hepatic parenchyma are presented in Table 4. FNH, hepatic adenoma, hemangioma, metastases, and intrahepatic cholangiocarcinoma demonstrated lesion stiffness greater than or comparable with that of the surrounding parenchyma.

In contrast, the mean stiffness of regenerating nodules and HCC was lower than that of the surrounding hepatic parenchyma. This finding is particularly relevant in cirrhotic liver, in which the background hepatic parenchyma may itself demonstrate increased stiffness because of fibrosis. Consequently, a malignant lesion does not

necessarily have a higher absolute stiffness than the surrounding liver.

Hepatocellular Carcinoma versus Regenerating Nodules: Among the lesions evaluated in cirrhotic liver, the mean SWE value of HCC was 16.6 kPa compared with 10.5 kPa for regenerating nodules. Thus, HCC demonstrated a higher mean stiffness than regenerating nodules in the present study. This observation suggests that SWE may provide complementary information when evaluating focal nodules in cirrhotic liver. However, the number of regenerating nodules was small, and no formal statistical comparison could be reconstructed from the available aggregate data. Therefore, this observation should be considered hypothesis-generating rather than evidence of a validated diagnostic cutoff.

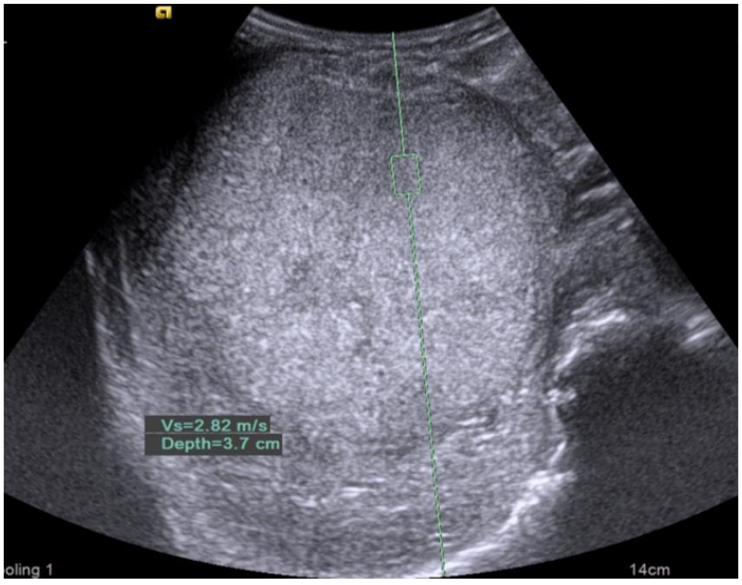

Figure 4: Ultrasound elastography in a case of HCC.

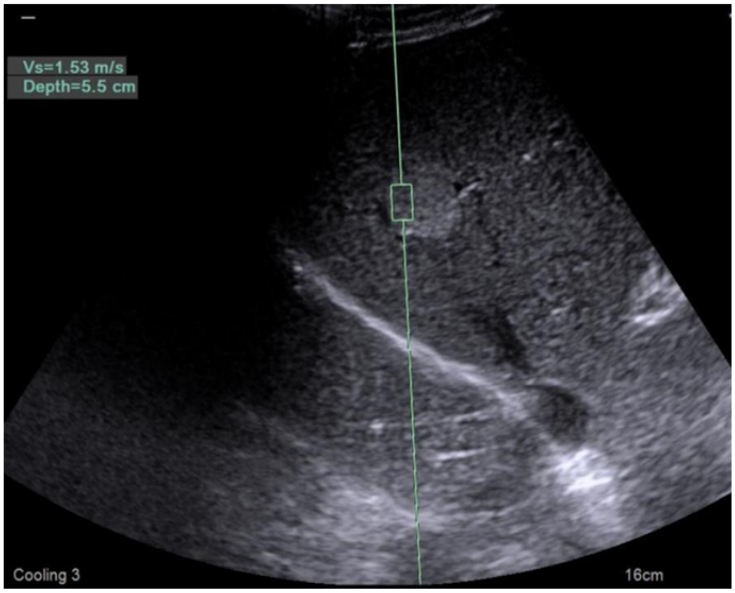

Figure 5: Ultrasound elastography in a haemangioma.

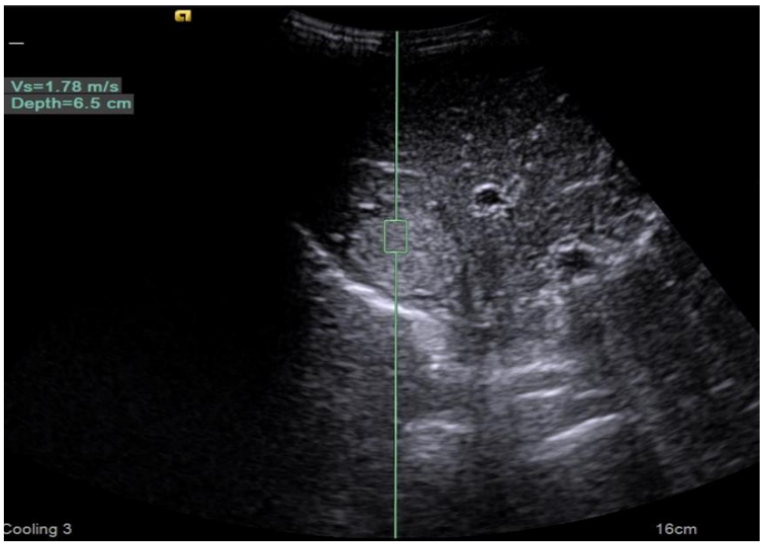

Figure 6: Ultrasound elastography in a focal nodular hyperplasia

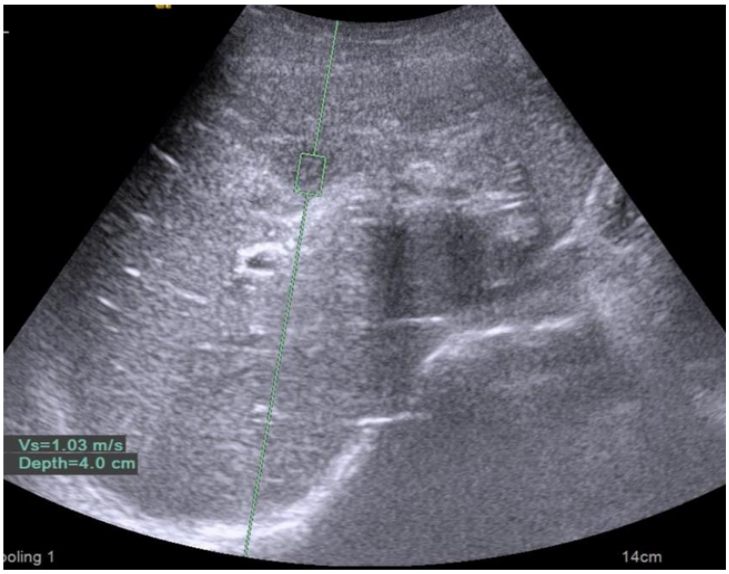

Figure 7: Ultrasound elastography in a hepatic adenoma

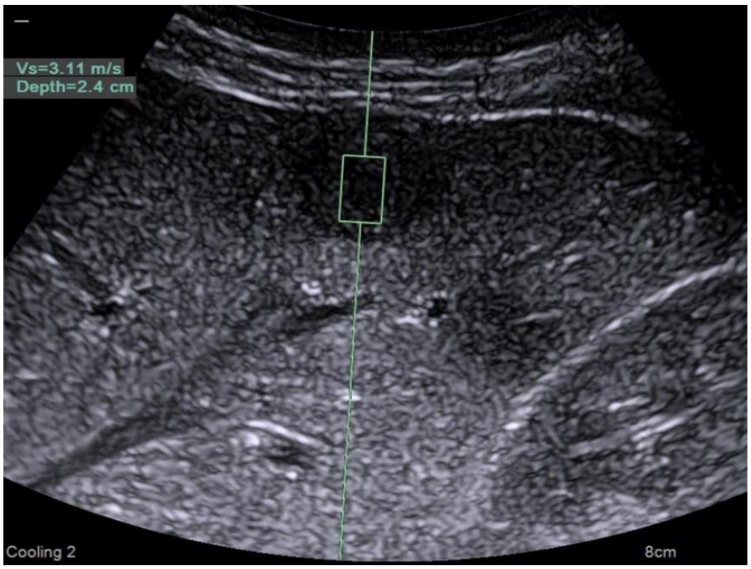

Figure 8: Ultrasound elastography in a metastasis

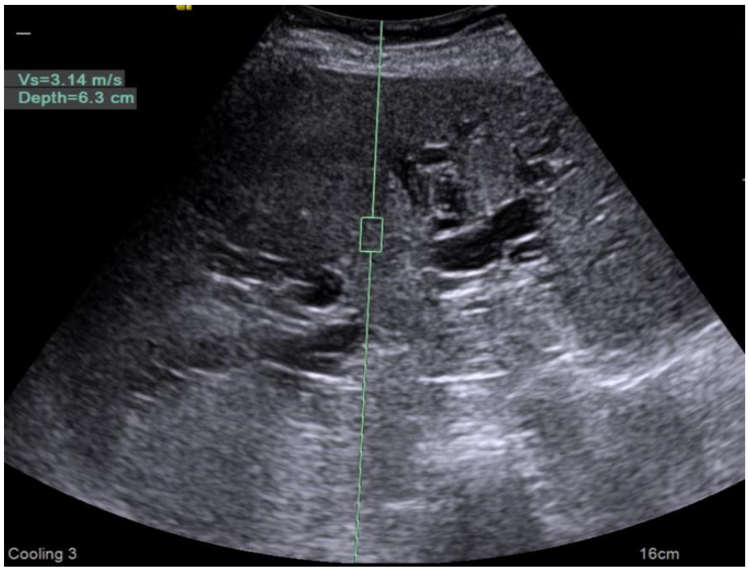

Figure 9: Ultrasound elastography in a cholangio-carcinoma

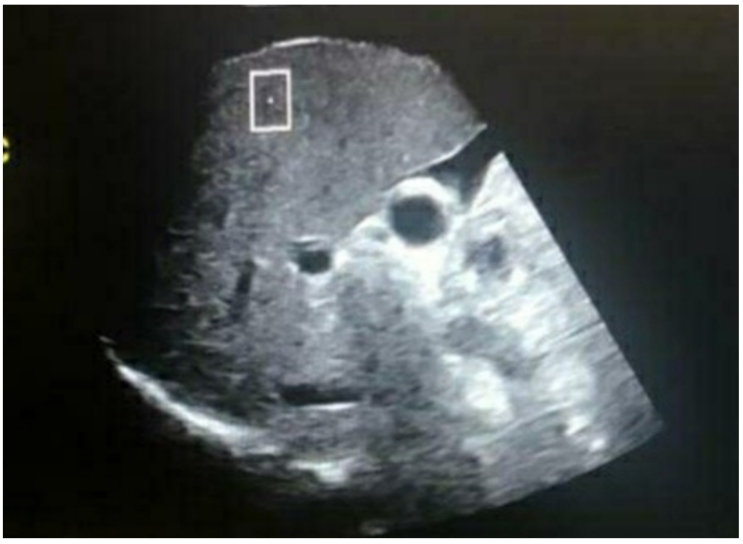

Figure 10: Ultrasound elastography in a regenerating nodule

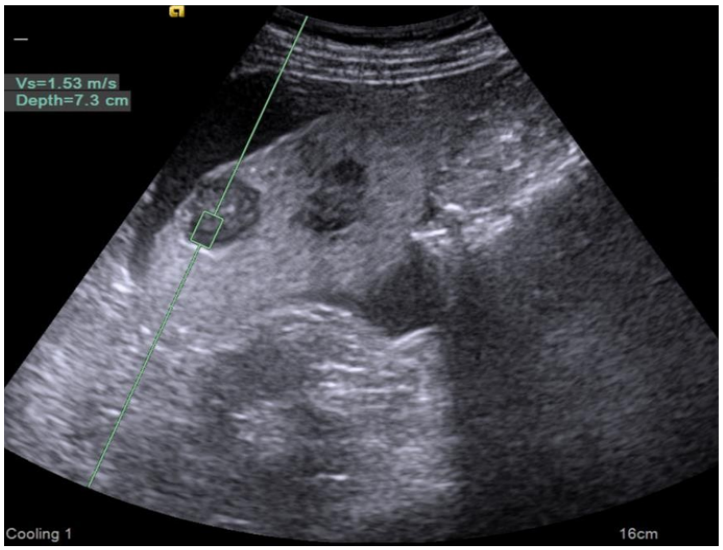

Figure 11: Ultrasound elastography in a case of cirrhosis

Discussion

The present prospective observational study evaluated the potential role of SWE in the characterization of focal liver lesions. The principal observation was that malignant lesions demonstrated a higher reported overall mean SWE value than benign lesions, with mean stiffness values of 25.0 kPa and 11.1 kPa, respectively. These findings are broadly consistent with the concept that tissue stiffness may vary according to lesion composition and pathological characteristics. Previous studies using ARFI, point SWE, and 2D-SWE have reported differences in stiffness among various focal liver lesion types. [6-10] However, stiffness measurements show substantial overlap among different lesions, and the interpretation of an absolute value must take into account the clinical context, background liver disease, lesion histology, and acquisition methodology. [7,8,12,13]

Benign Versus Malignant Lesions: In the present study, malignant lesions demonstrated a reported overall mean SWE value of 25.0 kPa compared with 11.1 kPa for benign lesions. Increased stiffness in malignant lesions may be related to increased cellularity, extracellular matrix deposition, fibrosis, desmoplastic stromal reaction, or other alterations in tissue architecture. A meta-analysis of 15 studies involving 1,894 liver lesions reported pooled sensitivity and specificity of 82% each for SWE in differentiating malignant from benign liver lesions, with an AUC of 0.89. [11] These findings support the potential diagnostic value of SWE but should not be interpreted as establishing a universal cutoff, because the underlying studies differed in ultrasound systems, techniques, lesion populations, and thresholds.

A prospective study of 2D-SWE reported significantly higher stiffness in malignant lesions than benign lesions and found particularly high values in cholangiocarcinoma. [9] Conversely, other studies have demonstrated substantial overlap in stiffness measurements. Therefore, the distinction between benign and malignant lesions should not be based on SWE alone. The findings of the present study are best interpreted as demonstrating that SWE can provide an additional quantitative parameter rather than as establishing a definitive benign-versus-malignant classification.

Hepatic Adenoma: Hepatic adenoma demonstrated a reported mean SWE value of 9.6 kPa, representing the lowest mean stiffness among the diagnostic categories in the present study. The relatively low stiffness may reflect the predominantly hepatocellular composition and limited fibrous stromal component of some adenomas. However, hepatic adenomas are histologically heterogeneous and may contain hemorrhage, necrosis, sinusoidal dilatation, steatosis, or inflammatory/fibrous components, all of which may influence elastographic measurements. Previous ARFI research has also demonstrated relatively low stiffness measurements in hepatic adenoma compared with several other focal liver lesions. [6] Because only three adenomas were included in the present study, the observed mean of 9.6 kPa should be regarded as descriptive and should not be considered a diagnostic cutoff.

Hemangioma: Hemangioma was the most common benign lesion in the present study and demonstrated a reported mean SWE value of 10.1 kPa. The stiffness of hemangiomas may vary according to vascular architecture and the amount of fibrous tissue within the lesion. Previous studies have demonstrated lower mean shear-wave measurements in hemangiomas than in several malignant hepatic tumors, supporting the potential role of elastography as an adjunctive technique. [6,10] However, a typical hemangioma can frequently be characterized using conventional and contrast-enhanced imaging. Therefore, SWE should not be used in isolation to establish the diagnosis of hemangioma.

Focal Nodular Hyperplasia: FNH demonstrated a reported mean SWE value of 15.3 kPa, which was higher than the mean values observed for hepatic adenoma and hemangioma. The relatively increased stiffness of FNH may be related to its fibrous components, including fibrous septa and the central scar in appropriate lesions. Previous 2D-SWE research has demonstrated relatively high stiffness values in FNH. These observations suggest that SWE may provide complementary information when FNH and adenoma are included in the differential diagnosis. Nevertheless, the small number of FNH cases in the present study prevents firm conclusions regarding the diagnostic utility of a specific stiffness value.

Hepatocellular Carcinoma: HCC demonstrated a reported mean SWE value of 16.6 kPa in the present study. An important observation was that the mean stiffness of HCC was lower than the mean stiffness of the surrounding hepatic parenchyma, which was 18.3 kPa. This finding illustrates an important principle in liver elastography: the absolute stiffness of a focal lesion must be interpreted in relation to the background liver. In patients with cirrhosis, the surrounding hepatic parenchyma may have substantially increased stiffness because of fibrosis. Consequently, an HCC may demonstrate lower stiffness than the cirrhotic background liver despite being malignant. This phenomenon has been described in previous studies. Hasab Allah et al. reported that HCC was significantly softer than the surrounding liver parenchyma in their study of focal liver lesions. [8] Lu et al. also demonstrated

the importance of considering both lesion stiffness and background liver stiffness in the characterization of focal liver lesions. [7] Therefore, the present findings reinforce the importance of interpreting SWE measurements within the context of the background liver rather than applying a simple assumption that every malignant lesion must be stiffer than the liver.

Regenerating Nodules: Regenerating nodules demonstrated a reported mean SWE value of 10.5 kPa. This was lower than the reported mean SWE value of 16.6 kPa for HCC. Differentiating HCC from benign or regenerative nodules in a cirrhotic liver is clinically important because both may appear as focal nodules on conventional ultrasound. The observed difference in mean stiffness suggests that SWE may provide complementary information in this setting. However, only four regenerating nodules were included. Therefore, the study does not provide sufficient evidence to establish a diagnostic threshold for distinguishing regenerating nodules from HCC. This finding should therefore be regarded as hypothesis-generating.

Metastatic Lesions: Metastatic lesions demonstrated a reported mean SWE value of 21.5 kPa. The mean stiffness of the surrounding liver in these patients was 10.0 kPa, making the metastases substantially stiffer than the background parenchyma in the present cohort. Increased stiffness of metastatic lesions may be related to tumor cellularity, extracellular matrix deposition, fibrosis, and stromal reaction. However, metastatic lesions arise from a wide range of primary malignancies and therefore have heterogeneous histological compositions. Previous studies have reported relatively high stiffness values in metastatic lesions, but substantial variation exists among different primary tumor types. [7-10] Consequently, a universal SWE threshold should not be assigned to metastatic disease on the basis of the present study.

Intrahepatic Cholangiocarcinoma: ICC demonstrated the highest reported mean SWE value in the present study, at 52.3 kPa. The relatively high stiffness may be related to the prominent fibrous and desmoplastic stromal component that is characteristic of many cholangiocarcinomas. Previous 2D-SWE studies have also reported relatively high stiffness in cholangiocarcinoma. Friedrich-Rust and colleagues reported cholangiocarcinoma as the stiffest malignant focal liver lesion category in their study. [9] Similarly, ARFI studies have demonstrated relatively high shear-wave velocities in cholangiocarcinoma compared with several other focal liver lesions. [6] However, only five ICC cases were included in the present study. Therefore, 52.3 kPa should be regarded solely as the observed mean in this small sample and must not be presented as a diagnostic cutoff or reference value.

Lesion Stiffness versus Background Liver Stiffness: An important finding of the present study was the variability in the relationship between lesion stiffness and background liver stiffness. The lesion-to-background relationship was particularly relevant for HCC and regenerating nodules. In cirrhotic liver, increased background stiffness may reduce the usefulness of an absolute lesion stiffness measurement. This has been demonstrated in previous research, in which lesion-to-background stiffness ratios provided additional information for selected diagnostic questions. [7,8] Lu et al. reported that stiffness measurements obtained from background liver more than 2 cm from the lesion had different variability compared with measurements obtained closer to the lesion and demonstrated that both absolute stiffness and stiffness ratios may have different diagnostic roles depending on the clinical question. [7] Hasab Allah et al. similarly reported that stiffness ratios could provide useful information, particularly for differentiating HCC from metastatic lesions. [8] Therefore, future studies should systematically investigate lesion-to-liver stiffness ratios rather than relying exclusively on absolute lesion stiffness.

Comparison with Previous Studies: The findings of the present study are broadly consistent with several previous investigations showing that elastography can provide additional quantitative information regarding focal liver lesions. [6-10] Gallotti et al. evaluated ARFI imaging in solid focal liver lesions and demonstrated different mean shear-wave velocities among lesion categories, with relatively low measurements in adenomas and higher measurements in several other lesions. [6] Lu et al. evaluated stiffness values and stiffness ratios in a large cohort and demonstrated that stiffness measurements could contribute to the differentiation of malignant and benign lesions. [7] Hasab Allah et al. evaluated point SWE in 197 patients with focal liver lesions and demonstrated that HCC could be softer than surrounding liver, emphasizing the importance of background liver stiffness and lesion-to-liver relationships. [8] A prospective study by Friedrich-Rust and colleagues evaluating 2D-SWE found significantly greater stiffness in malignant than benign focal liver lesions, with particularly high stiffness in cholangiocarcinoma. [9] Kim et al. evaluated ARFI elastography for focal hepatic tumors and reported differences between hemangiomas and malignant tumors. [10] At the same time, published literature demonstrates considerable heterogeneity. Differences among studies may result from:

- Different elastography technologies.

- Different ultrasound manufacturers and software.
- Differences in ROI size and placement.
- Differences in lesion depth.
- Differences in lesion size.
- Differences in background liver disease.
- Different breath-holding techniques.
- Differences in the reference standards.
- Histological heterogeneity within individual lesion categories.
- Different definitions of diagnostic thresholds.

These factors explain why absolute SWE values should not be transferred directly from one study or ultrasound system to another.

Clinical Significance: The principal potential advantage of SWE is that it adds quantitative tissue information to conventional ultrasound. In clinical practice, focal liver lesions should first be evaluated using B-mode ultrasonography and Doppler imaging. When the lesion remains indeterminate, elastography may provide additional information regarding tissue stiffness.

SWE may be particularly useful in selected situations, including:

- Evaluation of an indeterminate solid focal liver lesion.
- Comparison of lesion stiffness with the surrounding liver.
- Assessment of focal nodules in patients with chronic liver disease or cirrhosis.
- Additional characterization of lesions when conventional ultrasound findings overlap.
- Potential differentiation of selected benign lesions, such as FNH and adenoma.

However, SWE should not replace CEUS, contrast-enhanced CT, MRI, or histopathological examination when those investigations are clinically indicated.

Current evidence increasingly supports a multiparametric approach. Ruan et al. evaluated a combined SWE-CEUS algorithm in 171 focal liver lesions and reported an AUC of 0.89 for the combined approach compared with 0.83 for CEUS alone. The authors nevertheless emphasized the need for further validation, particularly across different liver backgrounds and institutions. [14]

Conclusion

Ultrasound shear-wave elastography is a quantitative technique that provides information regarding the mechanical properties of focal liver lesions. In the present study, malignant focal liver lesions demonstrated a higher reported overall mean stiffness than benign lesions, with mean SWE values of 25.0 kPa and 11.1 kPa, respectively. Among the benign lesions, hepatic adenoma demonstrated the lowest reported mean stiffness, whereas FNH demonstrated the highest. Among the malignant lesions, ICC demonstrated the highest reported mean stiffness, followed by metastases and HCC. HCC also demonstrated a higher mean stiffness than regenerating nodules in the cirrhotic liver subgroup, although the small number of regenerating nodules limits the strength and generalizability of this observation. The findings suggest that SWE may provide complementary quantitative information during the evaluation of focal liver lesions. However, substantial overlap may occur among different lesion types, and stiffness is influenced by lesion composition, background liver disease, acquisition technique, ROI placement, and ultrasound equipment. Therefore, SWE should not be considered a standalone diagnostic test. It should be interpreted together with clinical history, B-mode ultrasonography, color Doppler, and appropriate contrast-enhanced imaging, with histopathological assessment when clinically indicated.

Larger prospective multicenter studies using standardized SWE protocols, appropriate patient-level statistical analysis, and independent validation cohorts are required to establish the diagnostic performance and clinical applicability of SWE in focal liver lesion characterization.

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