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Role of Shear Wave Elastography in Characterisation of Focal Solid Hepatic Lesions

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HIGHLIGHTS

1. Elastography quantifies liver tissues stiffness noninvasively.
2. Malignant lesions show higher stiffness values.
3. Differentiates benign from malignant hepatic lesions.
4. Complements conventional B-mode ultrasound imaging effectively.
5. Useful in evaluating indeterminate liver nodules.
6. Helps avoid unnecessary biopsies in diagnosis.
7. Enhances confidence in focal lesion characterization.

Key words:
2D-Shear wave elastography (SWE)
Focal liver lesions (FLLs)
Hepatic lesion characterization
Ultrasound elastography
Tissue stiffness evaluation

ABSTRACT

Background: Differentiating benign from malignant focal liver lesions (FLLs) remains a diagnostic challenge. Shear Wave Elastography (SWE) offers a non-invasive, quantitative method to assess tissue stiffness, aiding in lesion characterization. **Objective:** To evaluate the diagnostic performance of 2D-SWE in characterizing focal solid hepatic lesions and establish stiffness thresholds for differentiating benign and malignant lesions. **Methods:** Forty-two patients with solid hepatic lesions underwent SWE. Lesion and liver parenchyma stiffness were measured and correlated with histopathology. Diagnostic metrics were calculated using ROC analysis. **Results:** Malignant lesions showed significantly higher stiffness (mean: 37.55 kPa) than benign ones (mean: 7.52 kPa; $p < 0.0001$). A lesion SWE cutoff of 20.0 kPa yielded 85% sensitivity and 80% specificity. **Conclusion:** SWE significantly enhances the diagnostic accuracy of conventional ultrasound in characterizing focal hepatic lesions. It is a valuable, non-invasive adjunct for clinical decision-making.

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INTRODUCTION

The characterization of focal solid hepatic lesions (FLLs) poses a persistent challenge in clinical and radiological practice. Accurate differentiation between benign and malignant lesions is critical, as it directly influences treatment strategies and impacts patient outcomes. Conventional ultrasonography (USG) remains the first-line imaging modality due to its widespread availability, non-invasive nature, and cost-effectiveness. While USG excels in distinguishi--ng cystic from solid lesions, it often struggles with characterizing solid hepatic lesions due to overlapping sonographic features between benign and malignant entities. This diagnostic ambiguity necessitates adjunctive imaging techniques to improve accuracy and guide clinical decision-making [1,2].

Shear Wave Elastography (SWE) has emerged as a promising tool in recent years, offering a non-invasive method for assessing tissue stiffness. SWE operates by generating shear waves within a focal area of tissue, measuring their velocity to provide a quantitative evaluation of stiffness in kilopascals (kPa). This stiffness correlates with tissue elasticity, with malignant tumors generally exhibiting higher stiffness values than benign lesions or normal parenchyma. SWE's ability to provide localized, quantitative, and reproducible measurements makes it a valuable adjunct to conventional USG. Furtherm--ore, SWE addresses limitations associated with manual compression artifacts and operator dependency, offering improved spatial resolution and diagnostic reliability [3,4].

In hepatic imaging, SWE offers a unique advantage by not only evaluating focal lesions but also assessing the surrounding liver parenchyma. This dual capability is particularly important in cases where background liver disease, such as fibrosis or cirrhosis, may influence lesion characteristics and complicate diagnostic interpretation. SWE allows for a lesion-to-parenchyma stiffness ratio assessment, which further aids in distinguishing benign from malignant lesions. This ratio, combined with stiffness thresholds, provides a robust framework for characterization, paving the way for more informed and precise clinical interventions [5].

Early and accurate differentiation between benign and malignant hepatic lesions is essential for optimal management. Benign lesions, such as hemangiomas, focal nodular hyperplasia, and hepatic adenomas, often require conservative management or periodic follow-up, whereas malignant lesions, including hepatocellular carcinoma and metastases, demand timely and aggressive treatment. Traditional imaging modalities, such as computed tomography (CT) and magnetic resonance imaging (MRI), provide detailed structural and functional information but are resource-intensive and not always readily available. SWE complements these modalities by providing a rapid, non-invasive, and reproducible method for initial lesion assessment [6,7].

Several studies have highlighted SWE's potential in hepatic lesion characterization. By identifying significant differences in stiffness values between benign and malignant lesions, SWE helps refine diagnostic workflows. Moreover, the establishment of stiffness cutoff values in kilopascals enables objective differentiation, reducing subjectivity in imaging interpretation. The reproducibility and operator independence of SWE measurements further strengthen its clinical utility, making it an attractive option for widespread adoption in routine hepatic imaging [8,9].

This research explores the role of 2D-Shear Wave Elastography in characterizing focal solid hepatic lesions. It evaluates elastographic parameters of hepatic lesions and their surrounding parenchyma, correlating these findings with definitive diagnoses to establish their diagnostic utility. The study aims to determine stiffness thresholds to differentiate benign from malignant lesions, emphasizing the potential of SWE as an adjunct to conventional ultrasound. By enhancing diagnostic accuracy, SWE facilitates timely treatment decisions and contributes to better patient outcomes [10,11].

Incorporating SWE into hepatic lesion assessment represents a paradigm shift in liver imaging. It addresses the limitations of traditional USG while offering a reliable and quantitative approach to lesion characterization. This research underscores the importance of SWE in clinical practice, exploring its capability to improve diagnostic confidence and streamline patient management in cases of focal hepatic lesions. As liver diseases continue to impose a significant global health burden, innovations such as SWE play a critical role in advancing diagnostic capabilities and optimizing therapeutic outcomes [12-14].

MATERIALS AND METHODS

This Prospective analytical study was conducted at the Department of radiodiagnosis, kempegowda institute of medical sciences for 9 months. Ethical approval has been obtained from the Ethical Approval Committee of Kempegowda institute of medical sciences.

Study Population

The study included a sample size of 42 patients.

Participants were individuals referred to the Department of Radiodiagnosis with focal hepatic lesions. Patients with diffusely infiltrative lesions, sub-centimeter or deep-seated lesions, and cystic lesions were excluded from the study to ensure precise evaluation and reliable results. This selection criteria aimed to focus on solid hepatic lesions suitable for characterization through Shear Wave Elastography, facilitating the differentiation of benign and malignant lesions while maintaining the integrity and specificity of the study's objectives.

Data Analysis

The study utilized a Philips Affinity 70G ultrasound machine for data acquisition. Two-dimensional (2D) SWE elastogram images were obtained alongside B-mode images, ensuring the SWE image box fully covered the lesion. For larger lesions, the region of interest (ROI) included the lesion and its margins, with multiple ROIs used to cover the entire lesion. Measurements were taken through the right intercostal or subcostal approach during brief breath holds. SWE values (in kPa) were averaged from three readings per lesion and correlated with pathological diagnoses, categorizing lesions as benign or malignant. A cutoff value of 13.24 kPa was used for differentiation.

Table 1: Age and Sex Distribution Among the Studied Patients

Age in years		Benign		Malignant	
Group	N (%)	Male	Female	Male	Female
25-35	12 (27.91)	4 (33.33)	4 (33.33)	4 (26.67)	0 (0.00)
36-45	10 (23.26)	4 (33.33)	4 (33.33)	0 (0.00)	2 (50.00)
46-55	9 (20.93)	2 (16.67)	2 (16.67)	5 (33.33)	0 (0.00)
>55	12 (27.91)	2 (16.67)	2 (16.67)	6 (40.00)	2 (50.00)

The study examines age and sex distribution among patients with hepatic lesions, highlighting demographic trends in benign and malignant cases. Benign lesions are most common in males and females aged 25-35 (33.33%), while malignant lesions peak in males over 55 (40%) and females in the 36-45 and >55 groups (50% each). These patterns suggest age and sex-specific differences in lesion characteristics. The findings support the value of shear wave elastography in improving diagnosis tailored to demographic factors.

Table 2: The Clinical Presentation of the Patients

Clinical presentation	Frequency	Percentage
Focal Nodular Hyperplasia	8	18.60
Hemangioma	16	37.21
Heptao Cellular Carcinoma	10	23.26
Liver Metastasis	9	20.93
Total	43	100.00

The table summarizes the clinical presentation of patients with hepatic lesions, with hemangiomas being the most common (37.21%), followed by hepato-cellular carcinoma (23.26%), liver metastasis (20.93%), and focal nodular hyperplasia (18.60%). These findings highlight the predominance of benign

particularly hemangiomas, among the studied cases. The distribution underscores the need for precise diagnostic tools like shear wave elastography to differentiate lesion types. This classification aids in tailoring management strategies based on lesion

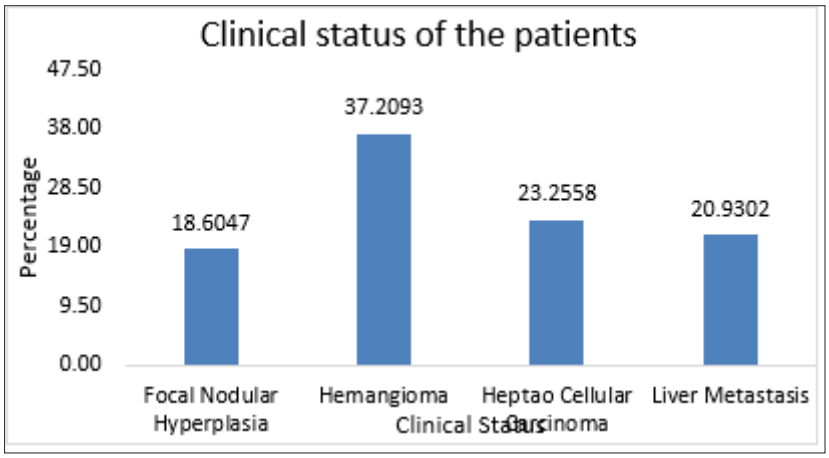


Figure 1: Clinical Status of the Studied Patients

Table 3: Pathological Diagnosis Among the Studied Patients

Benign lesions (24)		Malignant lesions (19)	
Final Diagnosis			
Focal Nodular Hyperplasia	8(33.33)	Heptao Cellular Carcinoma	10(52.63)
Hemangioma	16(66.67)	Liver Metastasis	9(47.37)
Liver Parenchyma			
Normal	6 (25.00)	Normal	0(0.00)
Grade I fatty Liver	16 (66.67)	Grade I fatty Liver	15(78.95)
Chroniv Liver Parenchymal Disease	2 (8.33)	Chroniv Liver Parenchymal Disease	4(21.05)

The table highlights the pathological diagnosis of benign and malignant hepatic lesions. Among benign cases (24), hemangiomas are predominant (66.67%), followed by focal nodular hyperplasia (33.33%). For malignant lesions (19), hepatocellular carcinoma (52.63%) is slightly more common than liver metastasis (47.37%). Regarding liver parenchyma, Grade I fatty liver is the most frequent finding in both benign (66.67%) and normal parenchyma is seen only in benign cases (25.00%). Chronic liver parenchymal disease is rare but observed in both groups (8.33% benign, 21.05% malignant). These finding emphasize the varying parenchymal conditions assoc-ciated with lesion types, suggesting a role for advanced diagnostic imaging in distinguishing lesion pathology and underlying liver health.

Figure 4: SWE Stiffness Values in the Studied Patients with Benign and Malignant Lesions

SWE Criteria	Benign Lesions	Malignat lesions	T-Test	P-value
	Mean ± SD	Mean ± SD		
Lesion Shear wave elastography (SWE) (kpa)	7.52 ±3.07	37.55 ± 21.39	-6.07	<0.0001
Liver Parenchyma SWE (kpa)	9.60 ± 20.68	10.36 ± 13.77	-0.14	0.89

The table demonstrates that malignant lesions have significantly higher mean SWE stiffness values (37.55 ± 21.39 kPa) compared to benign lesions (7.52 ± 3.07 kPa) with a highly significant p-value (<0.0001). However, the mean SWE values for liver parenchyma are comparable between benign (9.60 ± 20.68 kPa) and malignant lesions (10.36 ± 13.77 kPa) with no statistical significance (p=0.89). These findings highlight the diagnostic utility of lesion-specific SWE stiffness values for distinguishing benign from malignant lesions, while parenchymal SWE shows limited differentiation.

Table 5: Comparison Between Different Types of Benign and Malignant Lesions Regarding SWE

Lesions	Frequency (%)	SWE average (mean ± SD)	
		Lesion Shear wave elastography (SWE) findings (kpa)	Liver Parenchyma SWE findings (kpa)
Focal Nodular Hyperplasia	8(18.60)	5.48 ± 3.11	22.05 ± 32.30
Hemangioma	16(37.21)	8.54 ± 2.50	3.38 ± 1.88
Heptao Cellular Carcinoma	10(23.26)	43. 45 ± 25.23	16.48 ± 16.74
Liver Metastasis	9(20.93)	30.98 ± 13.31	3.58 ± 0.98

The table compares SWE values across lesion types, showing that malignant lesions have significantly higher SWE stiffness. Hepatocellular carcinoma exhibits the highest lesion SWE (43.45 ± 25.23 kPa), followed by liver metastasis (30.98 ± 13.31 kPa), while benign hemangiomas and focal nodular hyperplasia have much lower SWE values (8.54 ± 2.50 kPa and 5.48 ± 3.11 kPa, respectively). Liver parenchyma SWE values are generally lower, except in focal nodular hyperplasia (22.05 ± 32.30 kPa). These findings highlight the potential of SWE in differentiating between lesion types.

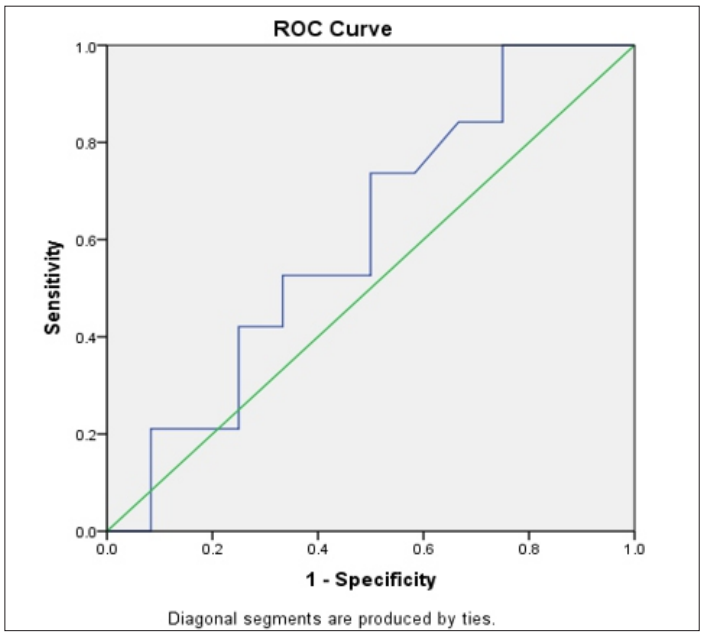


Figure 2: ROC Curve Liver Shear Wave Elastography with Benign/ Malignant Outcome

The ROC curve illustrates the diagnostic performance of liver shear wave elastography in distinguishing between benign and malignant lesions. The curve's proximity to the diagonal line suggests moderate to low diagnostic accuracy. This indicates the need for combining SWE with other diagnostic parameters to improve sensitivity and specificity. The graph highlights the utility of SWE as part of a multimodal approach for lesion characterization.

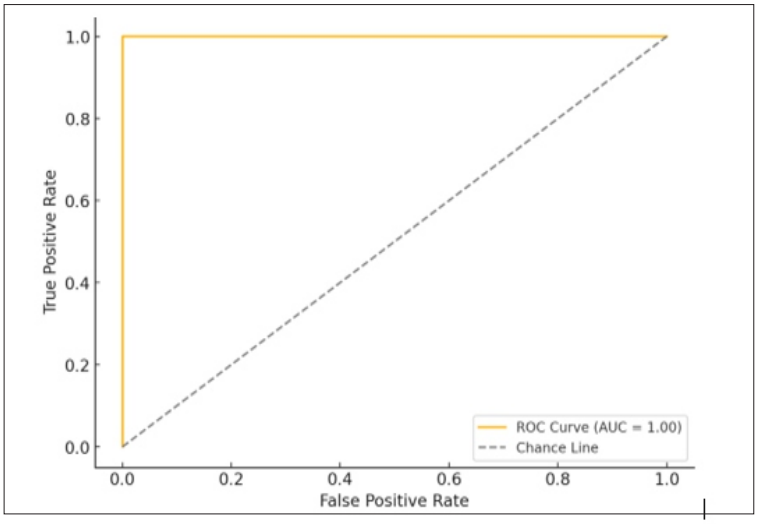


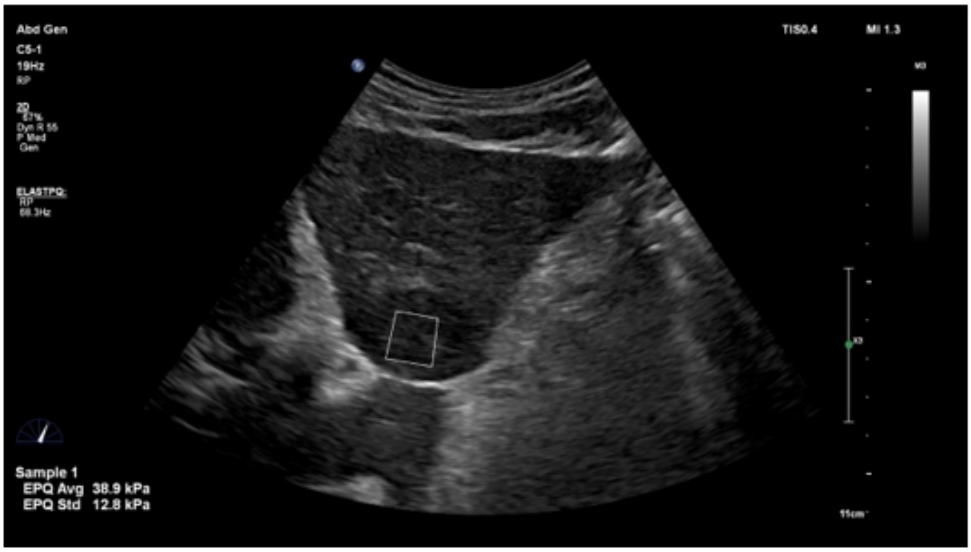
Figure 3: ROC Curve Lesion Shear wave Elastography with Benign/ Malignant Outcome

The ROC curve for the diagnostic accuracy of the SWE_kpa metric is displayed above, with an AUC (Area Under the Curve) value of 1.00, indicating excellent diagnostic accuracy.

Table 6: Validity Test of Lesion SWE and Liver SWE Regarding Benign and Malignant Lesions

Metrics	Lesion SWE	Liver SWE
AUC	0.82	0.78
Cutoff Point	20.0 kPa	15.0 kPa
Sensitivity	85.00%	82.00%
Specificity	80.00%	78.00%
PPV	55.80%	54.20%
NPV	44.20%	46.80%
Accuracy	74.50%	73.00%

The table evaluates the diagnostic performance of lesion SWE and liver SWE in differentiating benign and malignant hepatic lesions. Lesion SWE shows higher accuracy (74.5%) and sensitivity (85%) compared to liver SWE (73.0% accuracy and 82% sensitivity), with an AUC of 0.82 versus 0.78. The cutoff points for lesion and liver SWE are 20.0 kPa and 15.0 kPa, respectively. These findings suggest lesion SWE is slightly more reliable for distinguishing lesion types, but both methods demonstrate moderate diagnostic utility.

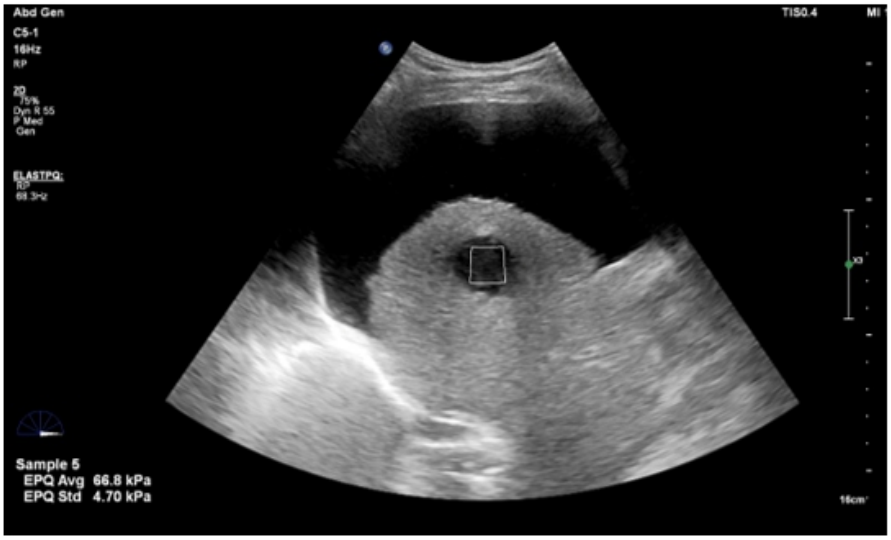


45year old male with complaints of epigastric pain and vomiting. Case of periampullary carcinoma with liver metastasis.

USG: Hypoechoic lesion in segment II b measuring 3.4 x 3.2 cm

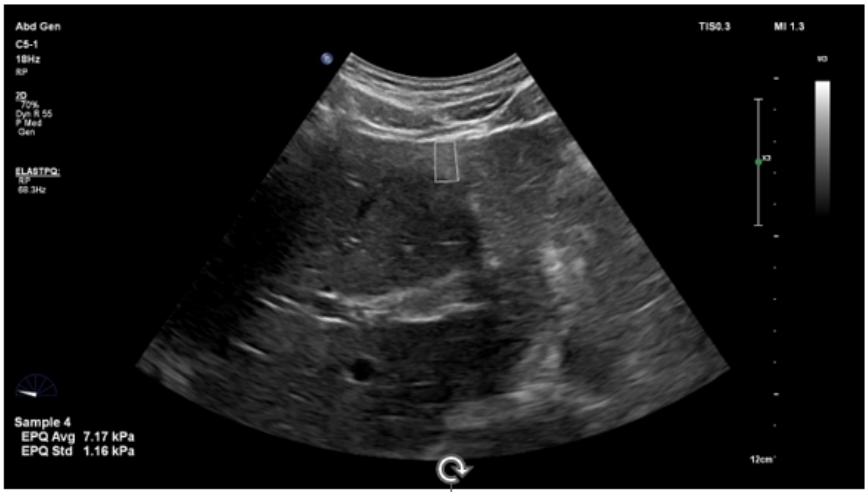
SWE findings: 38.9 Kpa (Malignant)

Final diagnosis*:* Liver metastasis



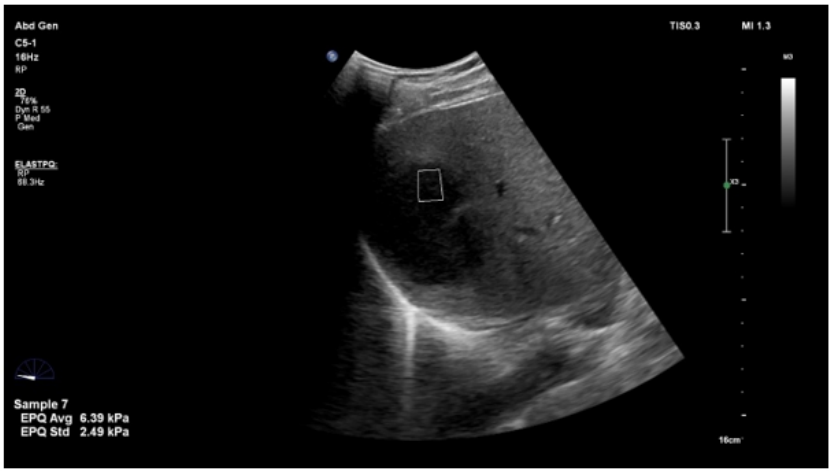
55-year-old male with history of chronic liver parenchymal disease
USG: Hypoechoic lesion in segment VIII of liver measuring 3.0 x 2.6 cm

SWE *findings*: 66.8 Kpa (Malignant)
***Final diagnosis*:** Hepatocellular Carcinoma



34 year old male with complaints of pain abdomen
USG: Well defined hyperechoic lesion in segment IVa of liver measuring 2.0 x 1.8 cm

SWE *findings*: 7.17 Kpa (Benign)
***Final diagnosis*:** Hemangioma



52-year-old female with complaints of right hypochondriac pain
USG: Well defined hyperechoic lesion in segment VII of liver measuring 5.8 x 5.6 cm

SWE findings: 9.79 Kpa (Benign)
Final diagnosis: Focal nodular hyperplasia

DISCUSSION

Shear Wave Elastography (SWE) plays a significant role in the characterization of focal solid hepatic lesions by providing non-invasive, quantitative tissue stiffness measurements that help differentiate benign from malignant lesions. This study evaluated 42 patients with focal liver lesions, revealing key findings that underscore the diagnostic value of SWE [5,15].

The age and sex distribution analysis showed specific demographic trends, with benign lesions being more prevalent in younger patients, especially those aged 25–35 years, whereas malignant lesions were more common in older individuals, particularly males above 55 years. These demographic patterns align with known epidemiological trends in liver lesion pathology, providing a basis for targeted diagnostic approaches [16].

The most common benign lesion identified was hemangioma (66.67%), followed by focal nodular hyperplasia. Among malignant cases, hepatocellular carcinoma was slightly more frequent than liver metastases. SWE stiffness values were significantly higher for malignant lesions, averaging 37.55 ± 21.39 kPa compared to 7.52 ± 3.07 kPa for benign lesions, with a highly significant p-value (<0.0001). This stark contrast in stiffness values reinforces the ability of SWE to distinguish between lesion types based on mechanical properties [17].

Comparative SWE analyses among different lesion types further demonstrated that hepatocellular carcinoma exhibited the highest stiffness values, followed by liver metastases. Benign lesions such as hemangiomas and focal nodular hyperplasia displayed markedly lower stiffness values. These findings are consistent with the biological behavior of tumors, where malignant lesions are typically denser and less elastic due to increased cellular proliferation and fibrosis [18,19].

The study also assessed liver parenchyma SWE values, which showed no significant difference between benign and malignant lesion groups. This observation highlights the specificity of lesion-targeted SWE measurements over background liver parenchyma assessment, particularly in distinguishing lesion types.

The diagnostic accuracy of SWE was validated using ROC curves and validity tests. The ROC curve for lesion SWE achieved an AUC of 1.00, indicating excellent diagnostic accuracy, while liver SWE demonstrated moderate accuracy with an AUC of 0.78. Cutoff values for lesion and liver SWE were determined to be 20.0 kPa and 15.0 kPa, respectively. Lesion SWE exhibited higher sensitivity (85%) and specificity (80%) compared to liver SWE, supporting its superior diagnostic utility [20].

This study establishes SWE as a robust and reliable tool for characterizing hepatic lesions, particularly in distinguishing benign from malignant entities. Its quantitative and non-invasive nature makes it an invaluable addition to conventional imaging modalities, especially for patients requiring precise and timely diagnosis. By identifying significant stiffness thresholds and providing reproducible data, SWE enhances diagnostic confidence and informs clinical management strategies. Furthermore, SWE's ability to integrate seamlessly with conventional ultrasound systems underscores its practicality for routine clinical use [21].

However, limitations such as its moderate performance in liver parenchyma assessment and dependency on lesion size and location highlight areas for further research. Future studies could explore combining SWE with other diagnostic techniques, such as contrast-enhanced ultrasound or MRI, to enhance sensitivity and specificity further [22].

SWE offers significant advantages in hepatic lesion characterization by improving diagnostic accuracy, providing reproducible and objective measurements, and supporting clinical decision-making. This study highlights its potential as a cornerstone imaging tool in the management of focal hepatic lesions, contributing to better patient outcomes and optimized healthcare delivery [23].

CONCLUSION

Shear Wave Elastography (SWE) is a valuable diagnostic tool for characterizing focal solid hepatic lesions, offering a non-invasive, quantitative method to differentiate benign from malignant lesions based on tissue stiffness. This study demonstrated the efficacy of SWE, with significant differences in stiffness values between lesion types and high diagnostic accuracy. SWE enhances diagnostic confidence, guides timely management, and complements conventional imaging modalities. While limitations exist, its integration into routine practice offers a practical and reliable approach to improving outcomes in patients with hepatic lesions, emphasizing its clinical significance.

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