# “2D SHEAR WAVE ELASTOGRAPHY TO EVALUATE FOCAL LIVER LESIONS - ONE YEAR HOSPITAL BASED OBSERVATIONAL STUDY”

**BY**

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**JAWAHARLAL NEHRU MEDICAL COLLEGE,**
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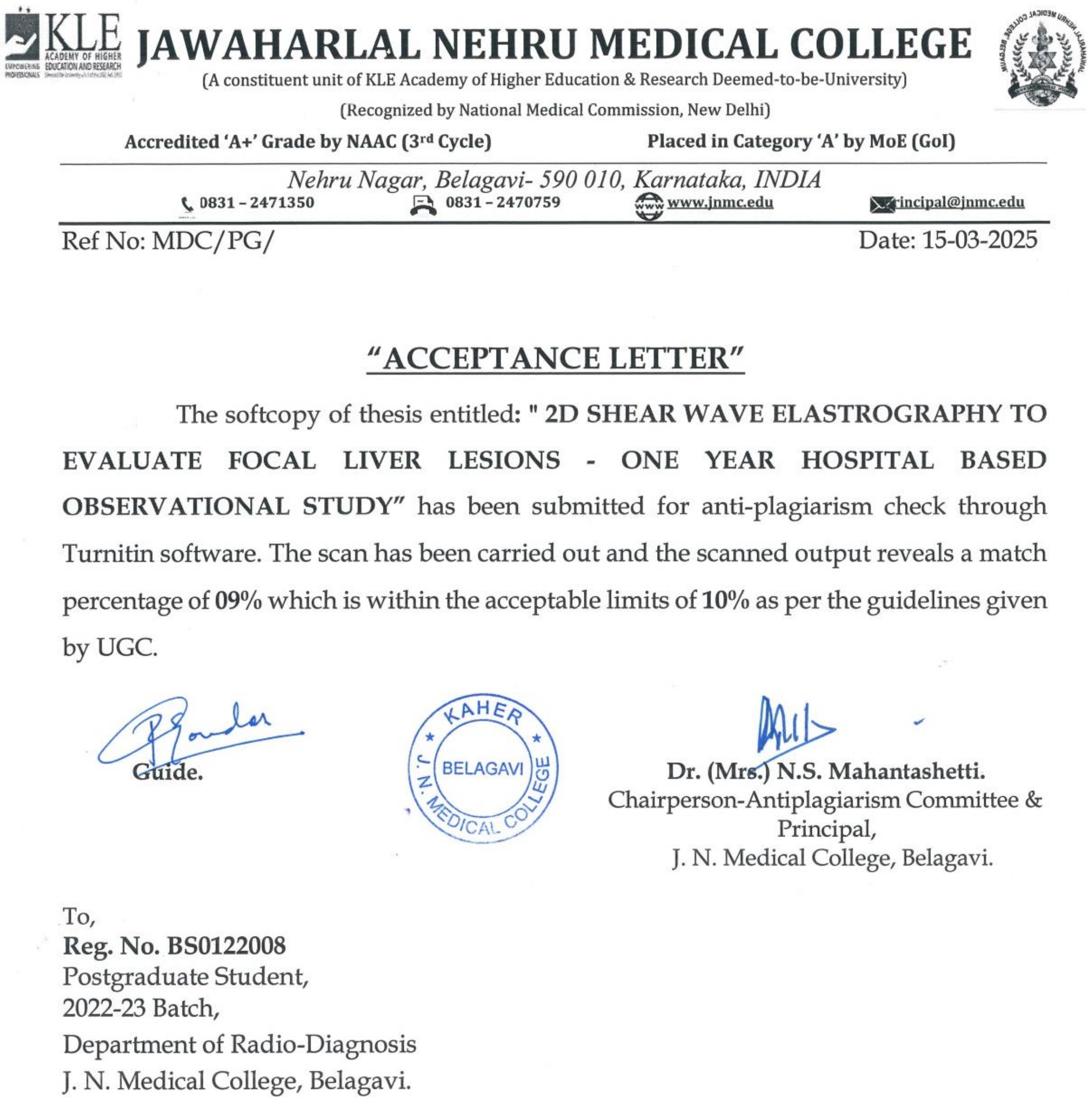

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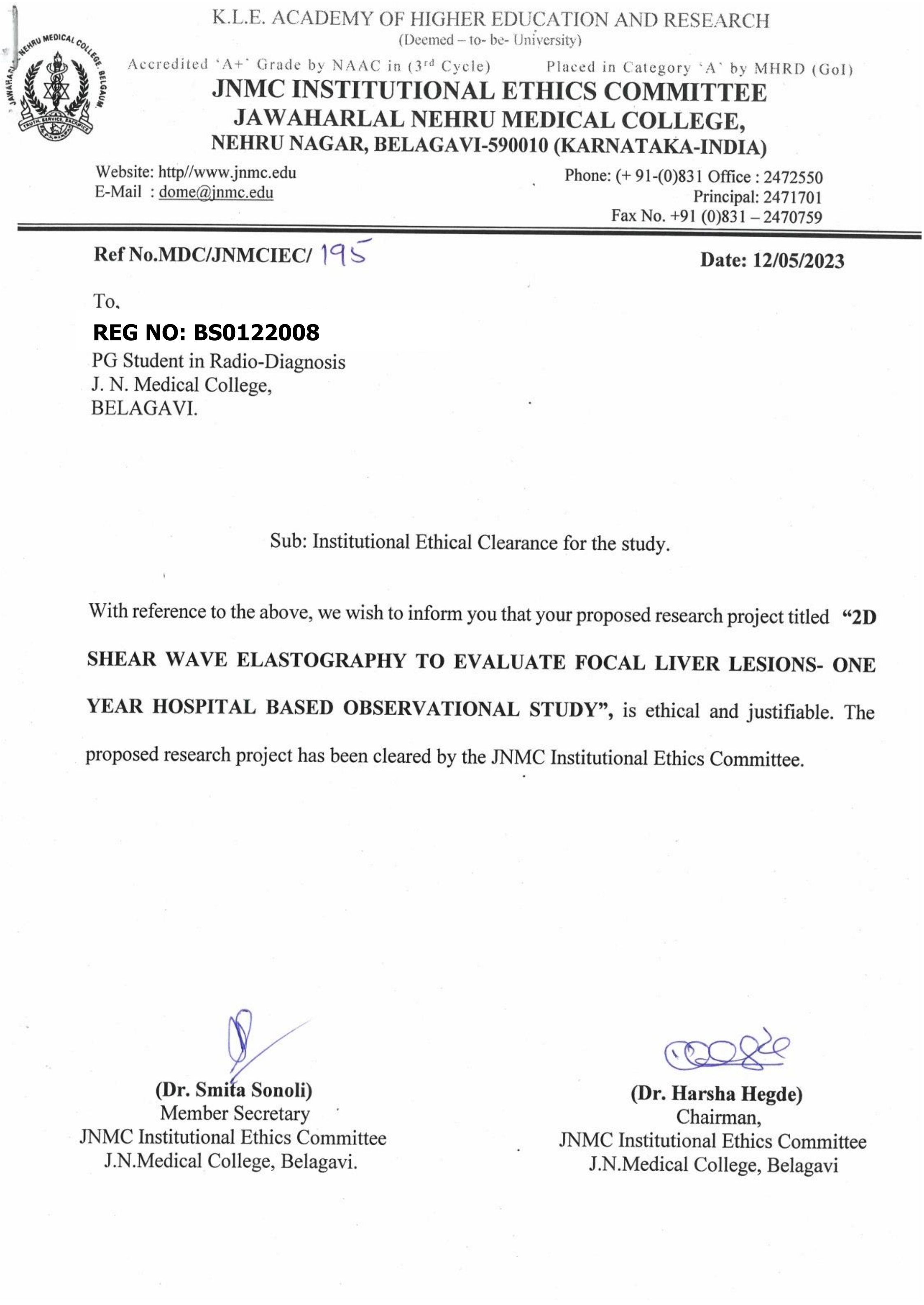

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# ABBREVIATIONS

| SL.NO | TYPES OF ABBREVIATION | |
|---|---|---|
| 1 | Shear Wave Elastography | (SWE) |
| 2 | Focal liver lesions | (FLLs) |
| 3 | Computed tomography | (CT) |
| 4 | Magnetic resonance imaging | (MRI) |
| 5 | Hepatocellular carcinoma | (HCC) |
| 6 | Ultrasound | (US) |
| 7 | Cholangiocarcinomas | (CCCs) |
| 8 | SWE-CEUS combined algorithm | (SCCA) |
| 9 | Focal liver lesion | (FLL) |
| 10 | Receiver operating characteristic | (ROC) |
| 11 | Hepatic focal lesions | (HFLs) |
| 12 | Coefficients of variation | (CVs) |
| 13 | Maximal elasticity | (Emax) |
| 14 | Shear wave dispersion | (SWD) |
| 15 | Focal nodular hyperplasia | (FNH) |
| 16 | Chronic liver disease | (CLD) |
| 17 | Area under the curve | AUC |
| 18 | Non- alcoholic fatty liver disease | (NAFLD) |
| 19 | Elevated alpha-fetoprotein | (AFP) |
| 20 | Continuing medical education | (CME) |

# ABSTRACT

Focal liver lesions (FLLs) are frequently seen in clinical practice, and proper differentiation between benign and malignant conditions is required for effective management. Conventional imaging techniques like ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) give structural information but do not offer quantitative measurement of tissue stiffness. This research investigates the clinical value of 2D Shear Wave Elastography (SWE) as a non-invasive diagnostic method in the characterization of FLLs. SWE measures liver stiffness by determining the velocity of propagating shear waves, providing real-time tissue elasticity mapping. Our hospital-based observational study over one year assessed the utility of SWE in differentiating between different FLLs, correlating its results with triple phase computed tomography results. Results show that malignant lesions had significantly greater stiffness values compared to benign counterparts, consistent with fibrosis and extracellular matrix deposition patterns. In addition, SWE was highly sensitive and specific in the diagnosis of hepatocellular carcinoma (HCC) and metastatic liver lesions. SWE is a safer, reproducible, and cost-effective method compared to traditional biopsy for early detection and monitoring of liver disease. This research highlights the promise of SWE in transforming liver imaging, minimizing invasive procedures, and enhancing diagnostic accuracy in everyday clinical practice.

**Keywords:** Shear Wave Elastography, Focal Liver Lesions, Liver Stiffness, Hepatocellular Carcinoma, Non-Invasive Imaging.

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# INTRODUCTION

Liver diseases continue to be a major worldwide health issue and account for a considerable amount of morbidity and mortality (1). The broad range of hepatic pathologies comprises viral hepatitis, alcoholic and non-alcoholic fatty liver disease, autoimmune diseases, and metabolic disorders (2). Of these, focal liver lesions (FLLs) are particularly challenging in terms of diagnosis and treatment. They include benign lesions like hemangiomas, focal nodular hyperplasia, and simple cysts, as well as malignant neoplasms like hepatocellular carcinoma (HCC) and metastatic disease (3). Correct, early characterization of FLLs is critical because misclassification can have a profound effect on patient management and prognosis. Imaging modalities, such as computed tomography (CT) and magnetic resonance imaging (MRI), are frequently used, but ultrasound (US) is still the most available and cost-effective first-line imaging modality (4).However, standard ultrasound may be unhelpful in distinguishing between benign and malignant lesions, particularly in those with underlying chronic liver disease (5).

Against this background, ultrasound elastography has come as a novel technique that employs the mechanism of tissue stiffness to aid in diagnosis (6). Elastography takes advantage of the fact that malignant lesions are generally stiffer than benign lesions because of greater cell density, fibrosis, and disrupted extracellular matrix. Among different elastography methods—including strain elastography, transient elastography, and point shear wave elastography—two-dimensional shear wave elastography (2D SWE) is unique with its real-time quantitative stiffness mapping within a predefined region of interest (7). When applied to the liver, 2D SWE can generate color-coded images reflecting differential tissue elasticity, which in turn assists in classifying the nature of a lesion (8). This capability is significant because focal lesions often present overlapping features on B-mode ultrasound alone.

Globally, the burden of malignant lesions like hepatocellular carcinoma is rising, partly due to an increasing prevalence of cirrhosis, chronic viral hepatitis, and metabolic syndrome. While benign lesions are frequently encountered and rarely require aggressive intervention, missing a malignancy or delaying its recognition can have dire consequences. At-risk populations, including those with chronic liver disease, often undergo periodic ultrasound surveillance (9). In such scenarios, an equivocal or suspicious lesion on grayscale ultrasound leads to further diagnostics, which might involve multiphase CT or MRI with potential limitations related to radiation exposure, cost, contrast allergies, and patient comorbidities. 2D SWE offers a non-invasive, radiation-free alternative for supplementing the information gleaned from standard ultrasound, potentially reducing the need for more invasive measures like biopsy when results are clearly benign or malignant (10).

Despite the promise of 2D SWE, the technique still warrants extensive validation. Most early studies focused on diffuse liver disorders, such as staging fibrosis in hepatitis B, hepatitis C, and non-alcoholic steatohepatitis (11). Research on focal lesions has been more limited, and results vary depending on study design, population characteristics, lesion types, and the specific ultrasound systems used (12). Nevertheless, many reports suggest that 2D SWE can reliably differentiate benign lesions—which tend to show lower stiffness—from malignant tumors that typically exhibit higher shear wave velocities (13). This diagnostic potential is a result of the pathophysiological changes in malignant lesions, including dense cellular architecture and desmoplastic reaction, both of which contribute to increased stiffness.

A significant advantage of 2D SWE is its capacity for real-time assessment, allowing clinicians to visualize both the lesion and the elastography overlay simultaneously (14). Since focal liver lesions can be heterogeneous, the ability to survey different areas of the lesion for stiffness values can enhance diagnostic accuracy. Additionally, 2D SWE facilitates repeat measurements during the same exam, which can be particularly useful in borderline or challenging cases (15). For patients who are poor candidates for MRI or contrast-enhanced CT—due to renal insufficiency, contraindication to contrast media, or severe comorbidities— 2D SWE represents a valuable alternative. It can also be performed at the bedside, enabling quick assessment in settings where rapid decisions are required, such as in critically ill patients (16).

Nevertheless, certain limitations constrain the widespread adoption of 2D SWE for FLLs. Operator experience, patient body habitus, and lesion location can influence image quality and measurement reliability (17). Deep-seated lesions or lesions obscured by overlying bowel gas may pose technical challenges. Furthermore, standardized cut-off values have yet to be universally agreed upon. Different ultrasound machines and software versions may yield variable numerical stiffness thresholds, complicating cross-study comparisons. In addition, the existence of underlying cirrhosis may enhance stiffness in the liver parenchyma itself, which may influence contrast between the lesion and the surrounding tissue. Consequently, in order to elucidate the diagnostic accuracy of 2D SWE in a variety of clinical contexts, establish dependable cut-off values for benign versus malignant lesions, and investigate the impact of confounding variables on measurement precision, it is necessary to conduct well-designed observational studies.

The current one-year hospital-based observational investigation endeavours to address these gaps by examining the capacity of 2D SWE to distinguish between benign and malignant focal liver lesions. This study aims to offer a perspective on the performance of 2D SWE in real-world clinical settings, as opposed to highly controlled research environments, by collecting data. One of the central questions is whether incorporating 2D SWE into routine ultrasound protocol can obviate diagnostic uncertainty sufficiently to restrict further cross- sectional imaging or invasive biopsy in a subset of cases (18). If 2D SWE is shown to be reliable and reproducible, it will simplify patient management by steering individuals with presumptively benign lesions towards conservative follow-up, yet also warn clinicians of suspected malignancies necessitating immediate histologic diagnosis or treatment.

Another possible direction for 2D SWE is in follow-up after treatment. As lesions at the foci are intervened upon with surgeries, radiofrequency ablation, or chemoembolization, the profile of stiffness evolves over time. Tracking those alterations would be useful in differentiating post-therapeutic necrosis from residual/recurrent tumor so that earlier intervention could be considered if necessary (19). Though this study focuses predominantly on the initial characterization of FLLs, future research might explore how 2D SWE can aid in long-term follow-up strategies.

In summary, 2D SWE is a non-invasive, promising accompaniment to conventional ultrasound. Early evidence indicates that it has the potential to provide valuable quantitative data for the classification of benign and malignant focal liver lesions based on rigidity. While limitations such as operator dependence and lack of universally accepted stiffness thresholds exist, ongoing technological refinements and accumulating clinical evidence are likely to improve its consistency (20). This thesis sets out to evaluate, over one year, whether 2D SWE can help clinicians avoid costly or invasive diagnostic methods and facilitate timely intervention for malignant lesions. By focusing on the primary objective—to distinguish benign from malignant FLLs—this study could elucidate the real-world utility of 2D SWE and contribute to guidelines that promote standardized use of elastography in hepatic imaging protocols.

This study's findings will be pertinent for radiologists, hepatologists, and other specialists involved in managing liver diseases. If 2D SWE demonstrates robust performance in a hospital-based setting, it could become an essential component of the imaging algorithm, particularly in resource-limited environments or for patients who cannot undergo contrast-enhanced studies(21). Ultimately, enhancing the reliability and availability of non-invasive techniques to characterize focal liver lesions can accelerate patient care pathways, minimize unnecessary biopsies or advanced imaging, and improve outcomes through earlier intervention when malignancies are detected promptly. This research underscores the evolving role of ultrasound elastography in modern hepatology. Through comprehensive data analysis and interpretation, the study will shed further light on 2D SWE's capability to accurately differentiate between benign and malignant focal liver lesions in a practical clinical environment, potentially informing future guidelines and standard-of-care practices.

# AIMS AND OBJECTIVES

## AIM

To assess the utility of two-dimensional (2D) Shear Wave Elastography in the evaluation of focal liver lesions.

## OBJECTIVES

1. To distinguish benign from malignant hepatic lesions using quantitative elastography values.
2. To compare the diagnostic performance of 2D Shear Wave Elastography with conventional ultrasound and other imaging modalities (CT/MRI).
3. To determine the feasibility and reproducibility of 2D Shear Wave Elastography in routine clinical practice.

## NEED FOR STUDY

2D Shear Wave Elastography (SWE) has been found to be an interesting, non-invasive imaging method that measures tissue stiffness, contributing to liver lesion characterization. It provides real-time, reproducible, and operator- independent measurements that may lower the requirement for invasive procedures. The objective of this research is to assess the diagnostic performance of SWE to differentiate benign and malignant liver lesions and compare it with the triple phase computed tomography. Institutionalizing SWE as a consistent tool in assessing hepatic lesions would enhance disease detection at the early stages, improve patient safety, and refine clinical decision-making, ultimately benefitting the care of liver ailments in contemporary medical practice.

# REVIEW OF LITERATURE

## Past Studies

1. Gerber et al. (2017) indicates that malignant FLLs exhibit significantly higher stiffness due to fibrosis and extracellular matrix remodeling. Among malignant lesions, cholangiocarcinomas (CCCs) demonstrate the highest stiffness, distinguishing them from hepatocellular carcinoma (HCC) and metastases (11). These findings underscore SWE's diagnostic utility in liver lesion evaluation.

2. Accurate differentiation of solid focal liver lesions (FLLs) is critical for guiding clinical management and prognosis. Traditional imaging techniques like ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) provide structural insights but lack functional assessment. Two-dimensional shear wave elastography (2D-SWE) is a promising non- invasive technique that quantifies liver stiffness, enhancing lesion characterization. Research by Guo et al. (2022) demonstrated that malignant FLLs exhibit significantly higher stiffness than benign ones, with liver metastases being the stiffest among malignant lesions (19). These findings confirm the utility of 2D-SWE as a valuable diagnostic adjunct to conventional imaging in differentiating FLL subtypes and improving diagnostic accuracy.

3. Ruan et al. (2023) emphasized the importance of accurately differentiating focal liver lesions (FLLs) for effective clinical management. Traditional imaging techniques, including ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI), provide structural insights but lack functional assessment (22). Their study demonstrated that combining shear- wave elastography (SWE) with contrast-enhanced ultrasound (CEUS) significantly

improved the diagnostic accuracy of FLL characterization. The SWE-CEUS combined algorithm (SCCA) showed superior sensitivity and specificity in distinguishing benign from malignant lesions, particularly in patients with normal liver backgrounds. These findings highlight SCCA’s potential as a reliable, non-invasive diagnostic tool, reducing the need for invasive biopsies.

**4.** Naganuma et al. (2020) highlighted the diagnostic challenges associated with two-dimensional shear wave elastography (2D-SWE) in liver imaging. Despite its growing use for liver disease assessment, artifactual images frequently occur, complicating interpretation. Their study demonstrated that chronic hepatic disease, liver cirrhosis, and anatomical irregularities can affect SWE accuracy (14). They emphasized that careful probe positioning and avoiding measurement behind focal lesions can improve diagnostic reliability. Additionally, 2D-SWE is valuable for detecting poorly visible lesions and distinguishing true tumors from pseudo-tumors, such as fatty changes. These findings underscore the importance of optimizing SWE protocols for accurate liver lesion characterization.

**5.** Babu et al. (2016) explored the role of elastography in chronic liver disease, emphasizing its non-invasive advantage over traditional liver biopsy. They highlighted ultrasound-based elastography (including shear-wave techniques) and magnetic resonance elastography (MRE) as key modalities for quantifying hepatic fibrosis, particularly in precirrhotic stages(23). These techniques outperform conventional imaging in fibrosis staging, treatment monitoring, and portal hypertension assessment. While elastography enhances chronic liver disease management, technical limitations, operator dependency, and patient-specific factors can impact accuracy. Their study underscores the evolving role of elastography in hepatic disease diagnosis, advocating for continued advancements in technique standardization and clinical application.

6. Taljanovic et al. (2017) explored the fundamental physics and clinical applications of shear-wave elastography (SWE), emphasizing its role in quantifying tissue stiffness. SWE, unlike conventional ultrasound, provides objective, quantitative, and reproducible elasticity measurements by generating shear waves perpendicular to the ultrasound beam (24). Originally developed for musculoskeletal imaging, SWE has expanded into liver imaging, where it enhances focal liver lesion (FLL) characterization by distinguishing malignant from benign lesions based on stiffness variations. Their study underscores SWE's growing clinical utility, offering real-time, non-invasive assessment of tissue elasticity, which aids in early disease detection, treatment monitoring, and improved diagnostic accuracy.

7. Nitta et al. (2021) reviewed physical and engineering factors influencing shear wave elastography (SWE), emphasizing their impact on shear wave speed (SWS) and elasticity measurements. They discussed tissue viscoelasticity, anisotropy, wave propagation, and mechanical properties, which can affect diagnostic accuracy (25). Additionally, technical aspects, such as region of interest depth and signal processing algorithms, influence SWE performance. Their study highlights the need for standardized interpretation methods to improve reliability in clinical applications, including focal liver lesion (FLL) differentiation. Understanding these factors is crucial for optimizing SWE accuracy, reducing artifacts, and enhancing its role as a non- invasive diagnostic tool.

**8.** Lu et al. (2021) explored the fundamental physics, clinical applications, and risks of elastography, emphasizing its role in quantifying tissue stiffness. They distinguished between strain elastography (manual compression-based) and shear wave elastography (SWE), which relies on acoustic radiation forces for quantitative stiffness measurements. Their study highlighted SWE's superiority due to its operator independence and ability to provide real-time, reproducible data (26). Clinically, SWE has expanded its diagnostic applications, particularly in liver disease evaluation. However, they also discussed potential limitations and risks, emphasizing the need for careful interpretation and standardized protocols to optimize SWE's effectiveness in differentiating focal liver lesions (FLLs).

**9.** Wen-Shuo Tian et al. (2016): Tian et al. evaluated the diagnostic efficacy of 2D shear wave elastography (2D-SWE) in differentiating malignant and benign focal liver lesions (FLLs). The study analyzed 229 FLLs in 221 patients, measuring Emax, Emin, Emean, and ESD values in kilopascals. The diagnostic efficacy was evaluated using receiver operating characteristic (ROC) analysis, and the inter-group differences were determined using the Mann-Whitney U-test (27). The authors stated that the Emax, Emin, Emean, and ESD values were significantly higher in malignant focal liver lesions than in benign ones ($p < 0.001$). The AUCs for malignancy detection were 0.920 (Emax), 0.710 (Emin), 0.879 (Emean), and 0.915 (ESD). The highest Emax among malignant lesions was reported for intrahepatic cholangiocarcinoma (96.21 ± 35.40 kPa), followed by liver metastases (90.32 ± 54.71 kPa) and hepatocellular carcinoma (61.83 ± 28.87 kPa) ($p < 0.0001$ and $p = 0.0237$, respectively). Among benign lesions, focal nodular hyperplasia (38.72 ± 18.65 kPa) showed significantly higher Emax than hemangiomas (20.56 ± 10.74kPa) (p = 0.0009). Also, the Emax values of adjacent liver parenchyma inhepatocellular carcinoma and intrahepatic cholangiocarcinoma are significantly higher than in other lesion types (p < 0.005). Therefore, the authors concluded that the Emax values of focal liver lesions and surrounding liver tissue assist in distinguishing malignant from benign lesions, showing the potential of 2D-SWE as a non-invasive diagnostic tool for liver lesion characterization.

**10.** Dena M. Serag (2020): In this study, Serag assessed how shear wave elastography (SWE) can assist in the diagnosis of benign hepatic focal lesions (HFLs) and malignant HFLs through the evaluation of tissue stiffness. A total of 110 patients (92 males, 18 females) with a mean age of 51.7 years (range: 30-70 years) were evaluated, including 28 patients with benign lesions and 82 patients with malignant lesions (28). The study reports that the stiffness was statistically different between malignant and benign lesions (p = 0.002). The mean stiffness values were 10.3 +/- 6.31 kPa for benign lesions and 16.2 +/- 9.32 kPa for malignant lesions. A cutoff value of 13.24 kPa was calculated to differentiate between the two groups, with sensitivity, specificity, and total accuracy of 78.04%, 71.42%, and 64.2%, respectively. In conclusion, SWE is a reliable non-invasive technique to differentiate between hepatic focal lesions. The evaluation of tissue stiffness adds information for the clinician to increase his diagnostic accuracy. Nevertheless, additional studies of far larger sample sizes and advanced SWE techniques might be required to better establish diagnostic sensitivity, improve test accuracy, and provide a standardized cutoff for wider clinical use.

11. **11.** Jeong Ah Hwang et.al (2019): Basic statistics were not available for the sample sizes for focal lesions of 10, 15, and 20 mm in size placed at depths of 3, 5, and 7 cm in a study jointly performed by Hwang et al. on the effect of prediction using two-dimensional (2D) shear wave elastography (SWE) on the appearance of stiffness and conspicuity of focal lesions in deep organs. The following criteria were used: two liver mimicking phantoms, a normal liver (4 ± 1 kPa) and a cirrhotic liver (16 ± 2 kPa) (29). Each examined three spherical inclusions (23 ± 3 kPa) at the selected depths of 3, 5, and 7 cm and 10, 15, and 20 mm in three studied sizes. The quantitative stiffness values and a five-grade qualitative morphologic score were recorded by two independent observers. The results showed that while background stiffness and depth of inclusion ($p < 0.001$) significantly influenced the stiffness values and coefficients of variation (CVs), the observer variability exerted minimal influence. Morphologic score varied significantly depending upon the size of lesions ($p < 0.001$), being lowest in the 10 mm inclusions. The stiffness values peaked at the 7 cm depth, with reliability of measurements decreasing with increasing depth. The study concluded that background stiffness and the depth of the lesion influence the assessment of lesions using 2D SWE; thus, there exist potential limitations in the assessment of deep hepatic lesions.

12. **12.** Zhang et. al. (2020): Zhang et al. examined the utility of shear wave elastography (SWE) using maximal elasticity (Emax) to differentiate between benign and malignant solid focal liver lesions (FLLs). In this prospective study, 152 FLLs were made up of 94 malignant (metastatic and hepatocellular carcinoma) and 58 benign (hemangioma, adenoma, and focal nodular hyperplasia) (13) . Suspicious findings were identified by conventional

ultrasound but not specific, hence SWE Emax measurement. Results showed that malignant lesions all had greater values of Emax (mean about 60 kPa) compared to benign lesions (mean about 20 kPa). Using a cutoff point of Emax = 34 kPa, the authors achieved a sensitivity of 89.4% and specificity of 86.2% with an AUC of 0.92. This was superior to using mean elasticity (Emean) values in isolation, which had an AUC of about 0.87. Notably, the study found that Emax was particularly beneficial in heterogeneous lesions, where stiff focal areas may substantially increase the maximum elasticity reading. The authors also conducted interobserver variability analyses and reported good agreement (intraclass correlation coefficient >0.90) in Emax measurements. Zhang et al. found that adding Emax to routine SWE protocols provides diagnostic accuracy, especially in patients whose lesions have mixed echo patterns on routine ultrasound. These results support the possibility of a more refined, quantitative liver lesion assessment, reducing unnecessary biopsies and maximizing early malignancy detection.

**13.** Mahmoud Abdel-Latif et al. (2020): They examined the function of shear wave elastography in the identification of benign and malignant focal lesions in the hepatic region. The investigation comprised 75 patients, of whom 52 had malignant and 23 had benign focal liver lesions. SWE measurements were obtained for both focal lesions and the adjacent hepatic parenchyma, with diagnostic confirmation obtained through a core needle biopsy (N=39) and contrast-enhanced CT/MRI (All cases) (30). According to the findings, the rigidity values of malignant lesions were significantly higher than those of benign lesions (20.22 vs. 10.68 kPa; $p < 0.001$). Within the subgroup of malignant lesions, CCC was reported as being stiffest, at 35.9 kPa, while the pattern within benign lesions showed notably that FNH had the highest stiffness, 26.7 kPa. A receiver operating characteristic analysis yielded a cutoff value of 14.165 kPa, with an area under the curve of 0.834. This results in a sensitivity of 98.1%, specificity of 78.3%, and accuracy of 92% in the differentiation of benign from malignant lesions. This study concluded that SWE, being an effective and a non-invasive technique, has a role in the characterization of benign from malignant focal liver lesions and may provide indications towards differentiating subtypes- HCC, CCC, and FNH.

**14.** Aymeric Guibal et al. (2013): Guibal et al. carried out a study to evaluate the elastic characteristics of focal liver lesions (FLLs) using shear wave elastography (SWE). The aggregate sample consisted of 108 patients with 161 FLLs, and stiffness measurements were carried out on both the lesions and the adjacent liver tissue. The Mann–Whitney test was implemented to evaluate the various categories of lesions, with a significance level of $p < 0.05$. In 13 patients, 22 nodules (14%) failed to acquire SWE, resulting in 139 lesions that were adequately evaluated (31). The mean stiffness values indicated were as follows (kPa): focal fatty sparing (6.6), adenomas (9.4), hemangiomas (13.8), FNH (33), scars (53.7), hepatocellular carcinoma (14.86), metastases (28.8), and cholangiocarcinomas (56.9). Significant differences in stiffness were noted between FNH and adenomas ($p = 0.0002$). HCC and cholangiocarcinomas also demonstrated significant differences ($p = 0.0004$). In addition, 50% of FNHs presented a radial pattern of increased elasticity, thus distinguishing them from adenomas. The study concluded that SWE is a good tool for differentiating FNH from adenomas and for HCC from cholangiocarcinomas, suggesting that it could become a good complement to conventional ultrasound in liver lesions classification. Besides, SWE may assist in diagnosing HCC in cirrhotic livers and will improve non-invasive methods for diagnosing liver diseases.

**15.** Dong et. al. (2020): Dong et al. examined the preliminary clinical use of shear wave dispersion (SWD) imaging for evaluating liver viscosity in the preoperative diagnosis of focal liver lesions (FLLs). Their prospective cohort included 52 patients scheduled for surgical resection, featuring 29 malignant tumors (hepatocellular carcinoma or metastatic nodules) and 23 benign lesions (hemangioma or focal nodular hyperplasia) (15). While traditional shear waveelastography measures tissue stiffness, SWD quantitatively assesses viscosity, offering an additional biomechanical parameter. Results showed that malignant lesions had higher SWD values—averaging around 10 Pa·s—compared to benign lesions, which generally remained below 6 Pa·s. The AUC for differentiating malignant from benign FLLs using SWD reached 0.88, with an optimal cutoff of 8 Pa·s, yielding a sensitivity of 85% and a specificity of 81%. The authors suggested that SWD might capture microenvironment changes such as cellular density and interstitial fluid alterations, potentially enhancing diagnostic confidence when combined with stiffness measurements. Although this initial study was limited by its sample size, Dong et al. highlighted the feasibility and strong correlation between SWD values and histopathological features, including tumor grade. They concluded that shear wave dispersion imaging holds promise as an adjunct to conventional elastography, potentially refining noninvasive FLL characterization and guiding operative planning. Further large-scale research was advocated to confirm these findings and establish standardized cutoffs.

**16.** Park et al. (2015): Park et al. evaluated intraobserver reproducibility and elasticity characteristics of focal liver lesions (FLLs) using SWE. These included 136 FLLs in 118 patients, each lesion being assessed quantitatively and qualitatively by three SWE images by a single radiologist (3).Reproducibility was assessed with ICC, while the differences in lesion stiffness were additionally analyzed. The findings demonstrated an overall ICC for intraobserver reproducibility of 0.763, suggesting good reliability. However, for lesions considered deep (≥6 cm within the liver), the overall reproducibility lowered significantly (ICC = 0.621) than those of the superficial (ICC = 0.793; p = 0.047). Malignant lesions (n = 85, mean stiffness = 60.41 ± 47.81 kPa) were significantly stiffer than benign (n = 51, mean stiffness = 22.05 ± 17.24 kPa, p < 0.0001). The hepatocellular carcinoma (HCC) among malignant lesions was less stiff (45.72 ± 35.65 kPa) than metastases (67.43 ± 43.39 kPa), but significantly stiffer than benign FLLs (22.05 ± 17.24 kPa). The ratio of lesion-to-parenchyma stiffness for HCC (3.76 ± 4.00) was not statistically different from benign FLLs (3.7 ± 3.77). The study concluded that SWE has very good intraobserver reproducibility influenced by lesion depth, while adding valuable insights into the difference in elasticity of FLLs, making it an important tool for non-invasive liver lesion characterization.

**17.** Ruan et al. (2023): Ruan et al. investigated the diagnostic performance of a shear-wave elastography (SWE) and contrast-enhanced ultrasound (CEUS) algorithm (SCCA) in differentiating focal liver lesions (FLLs). The study retrospectively analyzed 171 FLLs (124 malignant, 47 benign) from patients treated between January 2018 and December 2019 at the First Affiliated Hospital of Sun Yat-sen University (22). With the exception of haemangiomas and focal nodular hyperplasia (FNH), histopathology was the reference standard. SCCA implemented CEUS imaging and SWE stiffness thresholds of Lesions are classified as either <20 kPa or >90 kPa. The findings indicated that SCCA exhibited substantially superior diagnostic performance in comparison to CEUS alone. The sensitivity, specificity, and area under the curve (AUC) for the detection of malignant FLLs were 0.83, 91.94%, and 74.47% for CEUS and 0.89, 91.94%, and 85.11% for SCCA ($p = 0.019$). The decision curve analysis confirmed that SCCA offered superior clinical benefits, as evidenced by a net reclassification improvement index of 10.64% ($p = 0.018$) and an integrated discrimination improvement of 0.106 ($p = 0.019$). Subgroup analysis based on chronic liver disease status revealed no significant difference between CEUS and SCCA diagnoses in chronic liver disease patients. However, in patients with normal liver backgrounds, SCCA demonstrated significantly improved diagnostic accuracy (AUC: 0.89 vs. 0.83, $p = 0.018$). The study concluded that SCCA is an effective tool for differentiating FLLs in patients with normal liver backgrounds, though further validation is needed to confirm its applicability across diverse clinical settings.

**18.** Biris et al. (2024): Biris et al. conducted a comprehensive literature review to evaluate the efficacy of combining two-dimensional shear wave elastography (2D-SWE) and ultrasound-guided attenuation parameter (UGAP) in assessing the risk of progressive metabolic dysfunction-associated steatohepatitis (MASH) (32). The review examines the role of liver ultrasound in diagnosing metabolic liver diseases, focusing on recent advancements in non-invasive diagnostic techniques for steatotic liver disease (SLD). Liver ultrasound can detect a wide range of SLD manifestations, from metabolic dysfunction-associated liver disease (MASLD) to fibrosis, cirrhosis, inflammation, hepatitis, hepatocellular carcinoma (HCC), and other liver lesions. The integration of elastography and UGAP enhances ultrasound's diagnostic capability for accurate liver disease interpretation. The study highlights the progression of chronic liver diseases (CLD) from inflammation to fibrosis and cirrhosis, emphasizing the need for early detection strategies. MASLD affects approximately 20-25% of the global population, making early diagnosis crucial. The review underscores the growing role of non-invasive ultrasound- based tests in staging liver disease, offering a modernized diagnostic approach. By synthesizing current evidence, the study provides an updated perspective on ultrasound's evolving role in detecting and monitoring metabolic liver diseases.

**19.** Nacheva-Georgieva et. al. (2022): Nacheva-Georgieva et al. investigated the diagnostic utility of point shear wave elastography (pSWE) and two-dimensional shear wave elastography (2D SWE) in differentiating benign from malignant liver lesions (33). Their prospective study included 81 patients with 97 lesions—48 malignant (predominantly metastases and hepatocellular carcinoma) and 49 benign (hemangiomas and focal nodular hyperplasia). The authors found that both methods were significantly higher in malignant lesions, with mean pSWE readings around 3.5 m/s (~37 kPa) compared to 2.0 m/s (~15 kPa) in benign lesions. For 2D SWE, malignant lesions averaged 40 kPa versus 15 kPa in benign cases . When using optimal cutoff values (pSWE: 2.4 m/s; 2D SWE: 25 kPa), pSWE achieved a sensitivity of 85% and a specificity of 80%, while 2D SWE yielded a slightly higher sensitivity of 88% and specificity of 82%. The area under the curve (AUC) for 2D SWE was 0.91, edging past pSWE's AUC of 0.89. Interobserver agreement was slightly better for 2D SWE, with an intraclass correlation coefficient of 0.93 versus 0.90 for pSWE. The authors concluded that while both modalities effectively distinguish malignant from benign lesions, 2D SWE may offer marginally improved performance and user-friendliness, thanks to real-time imaging capabilities. This study thus underscores the growing clinical preference for 2D SWE in comprehensive hepatic imaging protocols, especially where quick, quantitative, and reproducible measurements are desired.

**20.** Shen et. al. (2024): Shen et al. introduced a non-invasive predictive model grounded in multimodality ultrasonography to differentiate malignant from benign focal liver lesions (FLLs). Their study enrolled 134 patients with 150 FLLs, employing B-mode ultrasound, color Doppler, and 2D shear wave elastography (SWE) to construct a combined diagnostic score. Malignant lesions consistently showed higher SWE values (>35 kPa) and increased intralesional vascularity on Doppler, whereas benign lesions typically had lower stiffness (<15 kPa) and mild vascular signals (34). By integrating these parameters, the predictive model achieved an AUC of 0.93, surpassing the performance of either modality alone (AUC for SWE=0.88; Doppler=0.80). Sensitivity reached 90.5% and specificity 88.2%, with an optimal cutoff score identified through logistic regression analysis. Shen et al. emphasized that their approach effectively minimized false positives stemming from atypical hemangiomas or regenerative nodules that can mimic malignant stiffness patterns. The authors also highlighted the model's potential for widespread clinical adoption, given the ubiquity of ultrasound equipment and operator familiarity. As a further step, they advocated for standardizing ultrasound protocols and training to ensure consistent image acquisition and interpretation.

These findings underscore the promise of combining SWE with advanced Doppler techniques, thereby bolstering early and accurate FLL characterization without resorting to more invasive procedures or costly cross- sectional imaging.

## Mechanism of 2D Shear Wave Elastography (DWS)

In 2D shear-wave elastography (SWE), a non-invasive ultrasound imaging technique provides real-time quantitative values for tissue stiffness. This may be achieved through measuring shear wave speed (SWS) (35). The principle behind this technique is that the speed of shear waves propagating through tissues is related to the stiffness of tissues: stiffer tissues allow shear waves to travel faster, while softer tissues allow shear waves to travel more slowly. Following the application of an external acoustic pulse, a shear wave is generated, which travels through the tissue perpendicular to the direction of the applied shear to produce a stiffness measurement. Then, ultrasound monitors the shear wave as it travels through tissues while gauging the velocity of the shear waves at several points. The shear wave speeds are then calculated and translated into tissue stiffness unit, which is typically reported in kilopascals (kPa).

In the context of focal liver lesions, the SWE is essential in differentiating between benign and malignant lesions. Malignant lesions are associated with fibrosis and alterations in tissue architecture correlating with cancer development; hence, stiffness here usually becomes higher. Therefore, shear waves will propagate more rapidly through malignant lesions than through benign lesions. For example, in hepatocellular carcinoma (HCC) or metastases, the tissue stiffness is generally increased due to a dense extracellular matrix, which is a distinguishing feature of malignant lesions (36). On the other hand, benign lesions, such as hemangiomas and focal nodular hyperplasia (FNH), are more likely to have lower stiffness values.

SWE is distinct from traditional imaging techniques in that it gives a functional measure of tissue stiffness, which can be important for liver disease diagnosis (liver fibrosis, cirrhosis) and also for the detection of malignant lesions. Clinicians can use SWE to provide real-time non-invasive evaluations, thus reducing the need for invasive biopsy procedures (32). This is beneficial because such procedures carry risks of complications or might be uncomfortable for patients. Thus, SWE has become an excellent technique for early detection and follow-up of liver diseases, especially in discriminating between benign and malignant focal liver lesions. The possibility of performing precise stiffness measurements with SWE permits repeated, longitudinal evaluations to monitor the progression of disease and response to therapy.

**SWE Performance in Differentiating Focal Liver Lesions (FLLs)**

Shear wave elastography (SWE) has proven to be an invaluable tool in the non- invasive assessment of focal liver lesions (FLLs), offering significant advantages in distinguishing between benign and malignant lesions (37). One of the key factors contributing to the effectiveness of SWE in this differentiation is its ability to quantify liver stiffness, which directly correlates with the pathological changes associated with various liver conditions. Malignant liver lesions, such as hepatocellular carcinoma (HCC), cholangiocarcinoma (CCC), and metastatic lesions, typically exhibit higher stiffness compared to benign lesions like hemangiomas, focal nodular hyperplasia (FNH), and liver cysts. This is because malignant lesions often involve increased extracellular matrix deposition, fibrosis, and altered tissue architecture, all of which result in stiffer tissue. SWE measures the shear wave speed (SWS), with faster propagation of shear waves indicating increased stiffness. Studies have shown that the stiffness values for malignant lesions are significantly higher, with hepatocellular carcinoma and cholangiocarcinomas presenting particularly elevated stiffness values compared to benign lesions (11). For instance, HCC often shows stiffness values ranging from 14.86 kPa to 45.72 kPa, while cholangiocarcinoma may range from 29.5 kPa to 56.9 kPa, significantly higher than benign lesions, such as FNH or hemangiomas, which exhibit much lower stiffness values (e.g., FNH: 16.6 kPa and hemangiomas: 13.8 kPa). The cut-off value for shear wave speed (e.g., 2.06 m/s for SWS) has been established in several studies to differentiate malignant from benign FLLs with high sensitivity and specificity. Moreover, SWE has shown strong diagnostic performance with Receiver Operating Characteristic (ROC) curve analysis, where AUC values (area under the curve) for SWE in distinguishing between malignant and benign FLLs are consistently high, often exceeding 0.90 (38). These findings underscore SWE's role as a reliable, real- time, and non-invasive tool for differentiating FLLs, reducing the need for invasive procedures like biopsy and aiding in timely, accurate diagnosis and treatment planning.

## Comparison of SWE with Other Imaging Techniques

Shear Wave Elastography (SWE) has emerged as a valuable non-invasive imaging technique in evaluating liver stiffness and diagnosing focal liver lesions (FLLs). When compared to traditional imaging modalities like CT (computed tomography) and MRI (magnetic resonance imaging), SWE offers several distinct advantages, particularly in its real-time, non-invasive nature, and the ability to quantify tissue stiffness, a critical parameter for assessing liver health and fibrosis progression (39). Unlike CT and MRI, which primarily focus on anatomical imaging and rely on indirect markers of liver pathology, SWE directly measures the mechanical properties of liver tissue by assessing shear wave velocity. This ability to quantify stiffness in real time provides clinicians with more precise and actionable insights into liver health, particularly in conditions like chronic liver disease, fibrosis, and hepatocellular carcinoma (HCC).

One of the key advantages of SWE is its real-time capability. Unlike CT and MRI, which typically take several minutes to generate detailed images of the liver, SWE can provide immediate feedback during the examination (40). This makes it a convenient option for point-of-care assessment, where the clinician can obtain and interpret results on the spot, without waiting for time-consuming imaging processes. SWE uses ultrasound waves to measure shear wave speed in liver tissue, which is directly related to stiffness. In comparison, CT and MRI provide structural images but do not offer direct measures of stiffness. While MRI elastography can offer stiffness data similar to SWE, it is more expensive and less widely available, making SWE a more practical option in many clinical settings (41).

Another significant benefit of SWE over CT and MRI is its non-invasive nature. CT and MRI, while invaluable in assessing liver morphology, come with certain drawbacks. Both techniques require the use of contrast agents for enhanced imaging, especially in cases where tumors or lesions need to be precisely visualized. These contrast agents carry inherent risks, such as allergic reactions, renal impairment, or contrast-induced nephropathy, particularly in patients with pre-existing kidney disease. In contrast, SWE does not require the use of contrast agents, making it a safer option, particularly for patients with renal insufficiency or those who are allergic to contrast materials. Moreover, SWE is radiation-free, whereas CT imaging involves ionizing radiation, which is a significant concern, especially when repeated imaging is necessary. The lack of ionizing radiation with SWE makes it an ideal choice for longitudinal monitoring of liver conditions, as repeated examinations can be done safely without the cumulative risks associated with radiation exposure.

In terms of monitoring liver fibrosis and lesions, SWE also has a clear edge over liver biopsy, which remains the gold standard for diagnosing fibrosis but has several limitations. Liver biopsy is an invasive procedure that carries risks of bleeding, infection, and discomfort for patients. It is also limited by its sampling error, as it only assesses a small portion of the liver, which may not represent the overall condition of the organ. Additionally, liver biopsy requires skilled personnel and may not be feasible for patients with certain medical conditions, such as coagulopathy. In contrast, SWE is non-invasive, easily repeatable, and can assess a larger area of the liver, providing a more comprehensive evaluation of liver stiffness. This is especially important for patients with chronic liver disease or those who need frequent monitoring for fibrosis progression. SWE can be used as a non-invasive alternative to liver biopsy, offering a safer, faster, and more comfortable approach for patients.

Furthermore, SWE has the potential to reduce healthcare costs associated with liver disease monitoring. By minimizing the need for frequent liver biopsies, it can provide a cost-effective solution for long-term management of chronic liver diseases like cirrhosis, NAFLD, and hepatitis. In addition, SWE’s real-time results allow for timely interventions in patients who might be at risk of disease progression, thereby improving patient outcomes and potentially reducing the need for more invasive treatments down the line.

In conclusion, while CT and MRI continue to play critical roles in liver imaging, particularly in assessing liver morphology and detecting masses, SWE offers a unique advantage in its ability to quantify liver stiffness, making it a powerful tool in diagnosing and monitoring liver conditions. The real-time feedback, non- invasive nature, and lack of radiation make SWE an excellent alternative to CT, MRI, and liver biopsy, particularly for routine monitoring of liver diseases. As such, SWE is becoming increasingly recognized as a reliable, practical, and cost- effective method for evaluating focal liver lesions, fibrosis, and other liver pathologies, providing valuable clinical insights without the limitations of more invasive techniques.

## Anatomy and Physiology of the Liver in Health and Disease

The liver, located in the upper right quadrant of the abdomen, is the largest organ in the body, weighing around 1500 grams. It is vital for processing blood that is rich in nutrients, which comes from the gastrointestinal tract, spleen, pancreas, and gallbladder. This blood enters the liver mainly through the portal vein and carries substances from digestion (42). Additionally, the liver receives blood from the hepatic artery, which supplies oxygenated blood from the aorta. The liver is responsible for over 500 metabolic functions, including the synthesis of glucose, plasma proteins, clotting factors, and urea, which are released into the bloodstream. It also produces bile, which is excreted into the intestine. The liver serves as a storage site for glycogen, fat, and fat-soluble vitamins (43). The portal vein provides low-pressure venous blood that has already lost much of its oxygen, while the hepatic artery delivers high-pressure, oxygen-rich blood. Both blood supplies merge in the liver’s capillary bed, from where the blood is drained via the central veins.

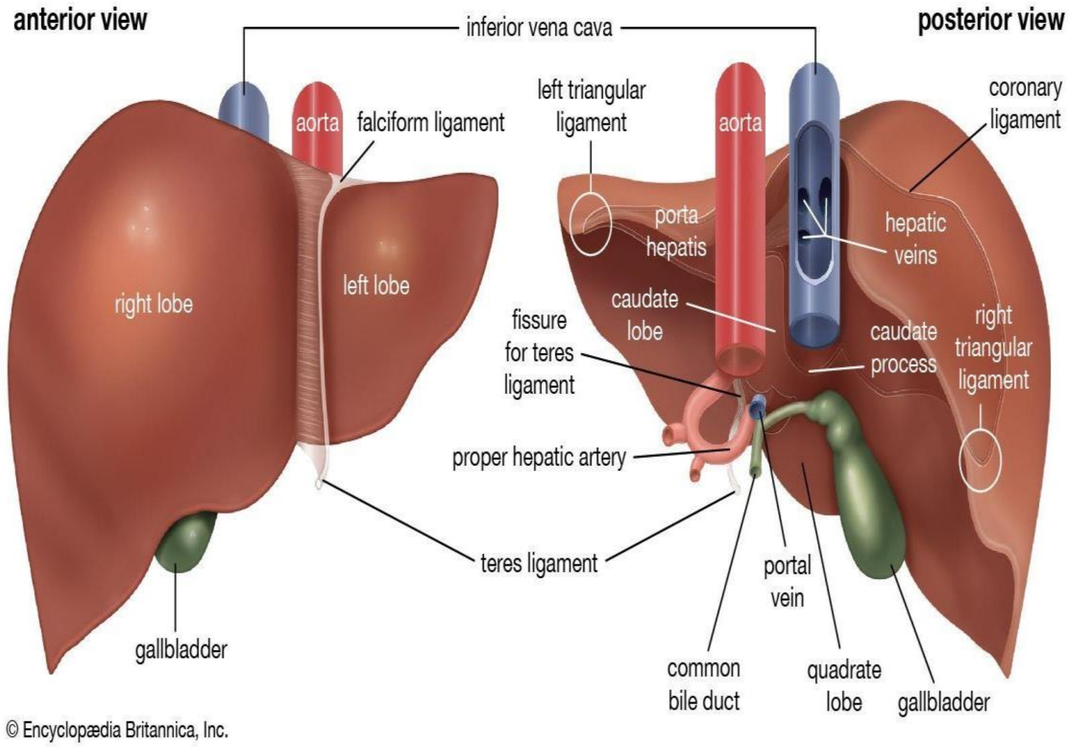

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**Figure 2.1: The liver**

The liver's basic architecture involves a complex network of blood vessels, lymphatics, nerves, and bile ducts, all of which converge at the hilus of the liver. From this point, they branch extensively within the liver to form a structure known as the portal canal (44). The portal vein enters the liver through this canal, eventually branching out to drain into the sinusoids, which act as the capillary network of the liver. Here, the blood from the portal vein mixes with the oxygenated blood from the hepatic artery. After passing through the sinusoids, the blood is collected in the central vein, which then drains the liver through the hepatic vein.

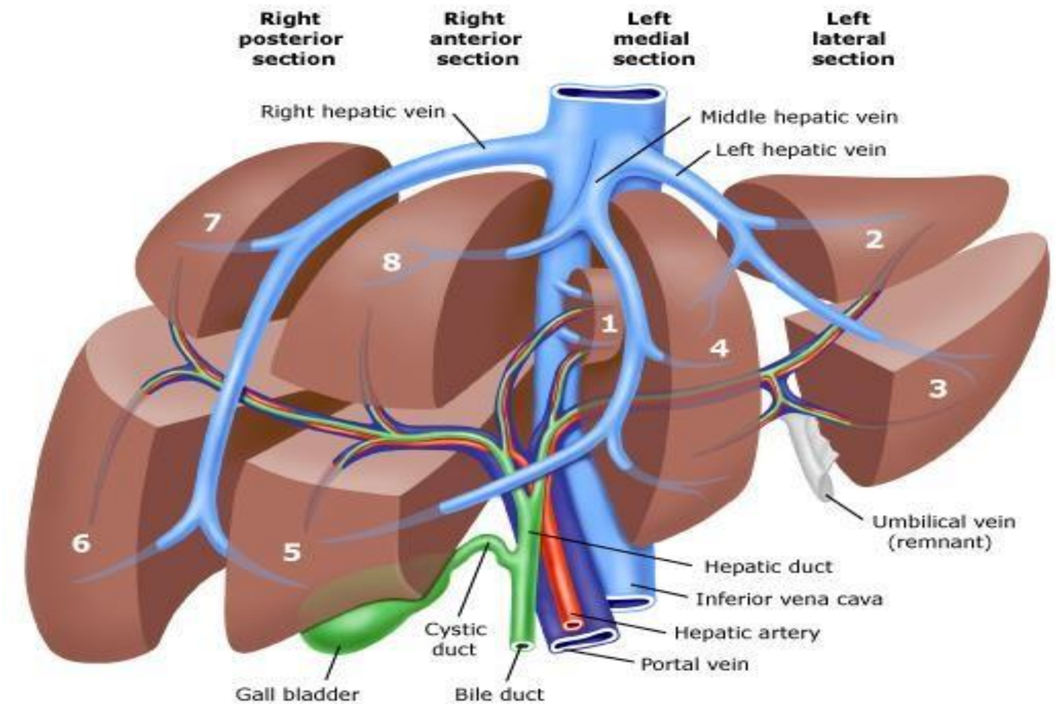

**Figure 2.2: Liver blood network.**

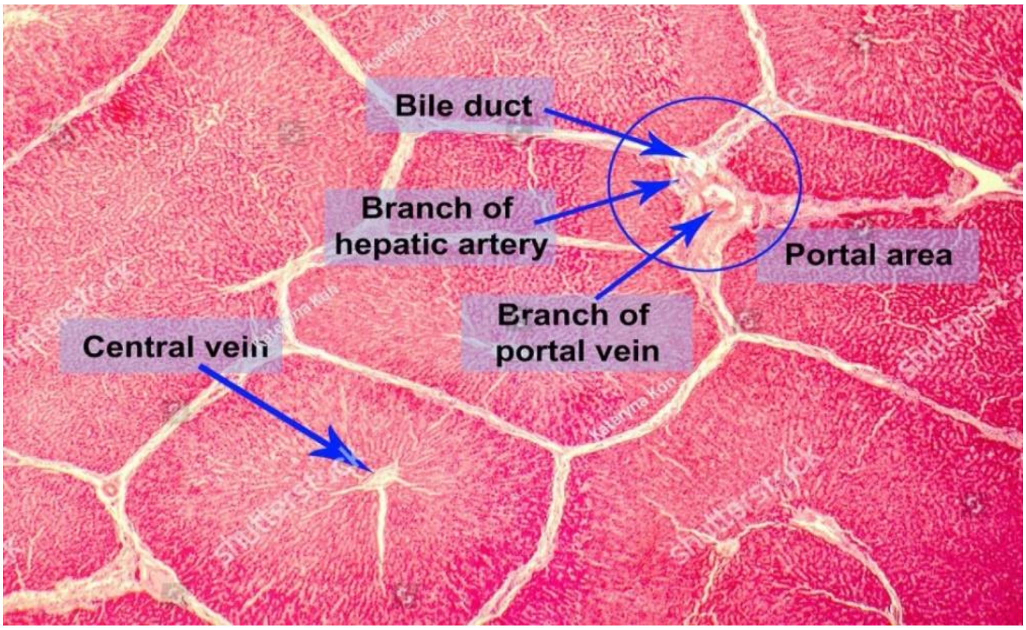

**Figure 2.3 The liver lobule with central vein and portal area Sinusoids**

The functional unit of the liver is the lobule, typically a hexagonal structure with three portal canals at the corners, all converging into a central vein. Within the lobule, hepatocytes (liver cells) are arranged in interconnected plates, with the space between them forming the sinusoids. The liver’s acinus, another key functional unit, consists of a portal canal at its center, with central veins at the corners. The acinus is divided into three zones: the periportal zone, the central zone, and the midzonal area between the two.

Sinusoids are specialized channels formed between the plates of hepatocytes in the liver. These canals, typically 8-10 µm in diameter, are comparable in size to capillaries and are arranged in a radial pattern within the liver lobule. Lining the walls of sinusoids are endothelial cells and Kupffer cells, which play a vital role in phagocytosis (45). The blood plasma and proteins pass through the endothelial cells via fenestrations (100-150 nm), reaching the Space of Disse, where they come into direct contact with hepatocytes. This enables nutrient and oxygen uptake by the liver cells.

On the opposite side of the hepatocyte plates are the bile canaliculi, which are 1µm in diameter. The bile produced by hepatocytes enters the bile canaliculi and flows towards the portal canal, eventually traveling to the bile ductules and bile ducts. Finally, it is stored in the gallbladder for digestive processes in the intestine. Interestingly, the flow of bile is opposite to the flow of blood through the sinusoids.

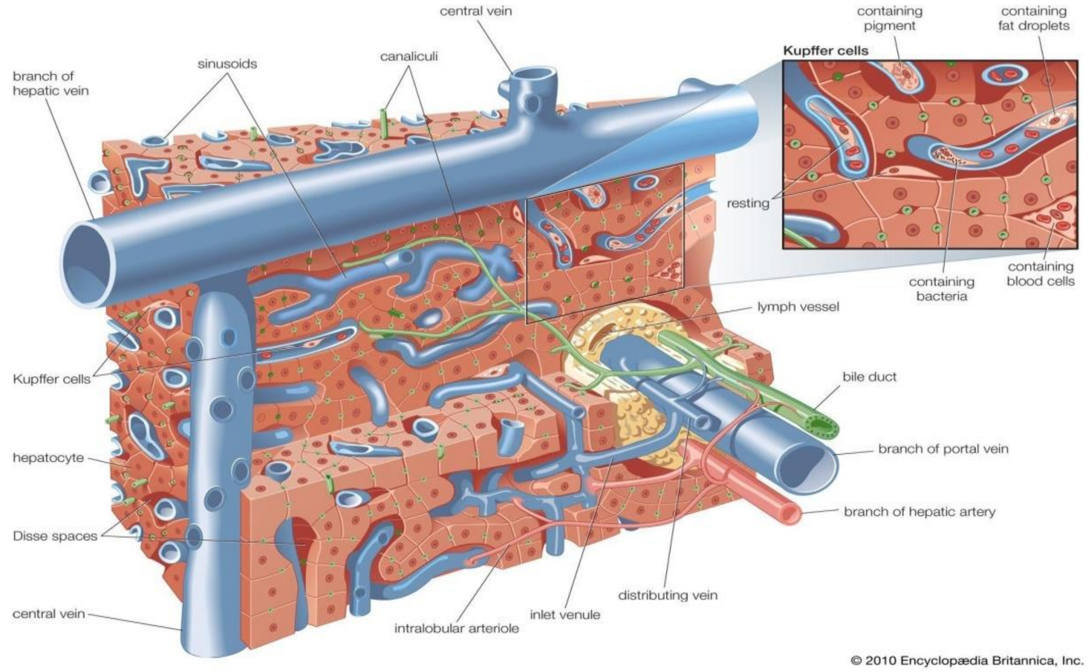

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**Figure 2.4: In-depth depiction of the liver's sinusoidal structure.**

**Pressure Distribution**

Blood pressure in the liver's afferent vessels and its distribution within the liver are largely consistent across various species. The pressure in the hepatic artery, which originates from the descending aorta and celiac trunk, mirrors that of the aorta, with high pulsatile pressure ranging between 120 to 80 mmHg, corresponding to the heart rate. As the hepatic artery branches inside the liver, the vessel compliance causes a gradual reduction in pulsation (46). By the time the blood reaches the sinusoids, the pulsation amplitude nearly vanishes, and the pressure drops to around 2-5 mmHg. In contrast, pressure in the portal vein, which comes from the capillaries of the digestive tract, remains non-pulsatile and is generally around 10-12 mmHg. Within the sinusoids, both portal venous and hepatic arterial pressures are approximately 3-5 mmHg. The pressure drop from the central veins to the vena cava is minimal, fluctuating slightly with respiration, with a range of 1-3 mmHg.

## Flow Distribution

The total liver blood flow in humans accounts for around 25% of cardiac output, or roughly 1500 ml/min. This flow is divided between the hepatic artery (about 25-30% or 500 ml/min) and the portal vein (about 70-75% or 1000 ml/min). When adjusted for liver size, this translates to approximately 100 ml/min per 100 g of liver tissue (47). Across species, the liver's blood flow per unit mass remains consistent at 100-130 ml/min per 100 g. The hepatic artery supplies 65% of the liver's oxygen needs, also playing a key role in the perfusing blood vessel walls and maintaining bile duct integrity. Meanwhile, portal venous blood, rich in nutrients, enables the hepatocytes to function effectively. Recent studies suggest that arterial and portal blood flow through both shared and distinct channels in the liver. The hepatic artery follows a spotty pattern in perfusing the liver, while the portal vein distributes blood more uniformly. Additionally, the liver regulates arterial flow via sphincters located at the sinusoidal inlets and outlets, ensuring consistent oxygen supply. When oxygen levels fluctuate, these sphincters adjust to alter the arterial-to-portal blood flow ratio.

## Overview of Focal Liver Lesions (FLLs)

Focal liver lesions (FLLs) are areas of abnormal tissue within the liver, commonly detected through imaging techniques like ultrasound, CT scans, and MRIs. These lesions can appear as either solid or cystic masses that are distinct from the surrounding healthy liver tissue (48). While the majority of FLLs are benign and non-cancerous, careful evaluation is critical to rule out potentially malignant lesions such as liver cancer. The management of FLLs is highly dependent on several factors, including the size, location, and patient's clinical history, all of which contribute to the decision-making process regarding treatment or monitoring strategies.

Prevalence of Focal Liver Lesions (FLLs) Focal liver lesions are increasingly detected due to the widespread use of abdominal imaging for routine health check-ups. These lesions are often found incidentally, and the majority do not exhibit symptoms, meaning they are asymptomatic (49). The prevalence of FLLs has risen with advanced imaging technology, allowing healthcare providers to identify lesions that were previously undetectable, further emphasizing the importance of imaging in liver health management (50).

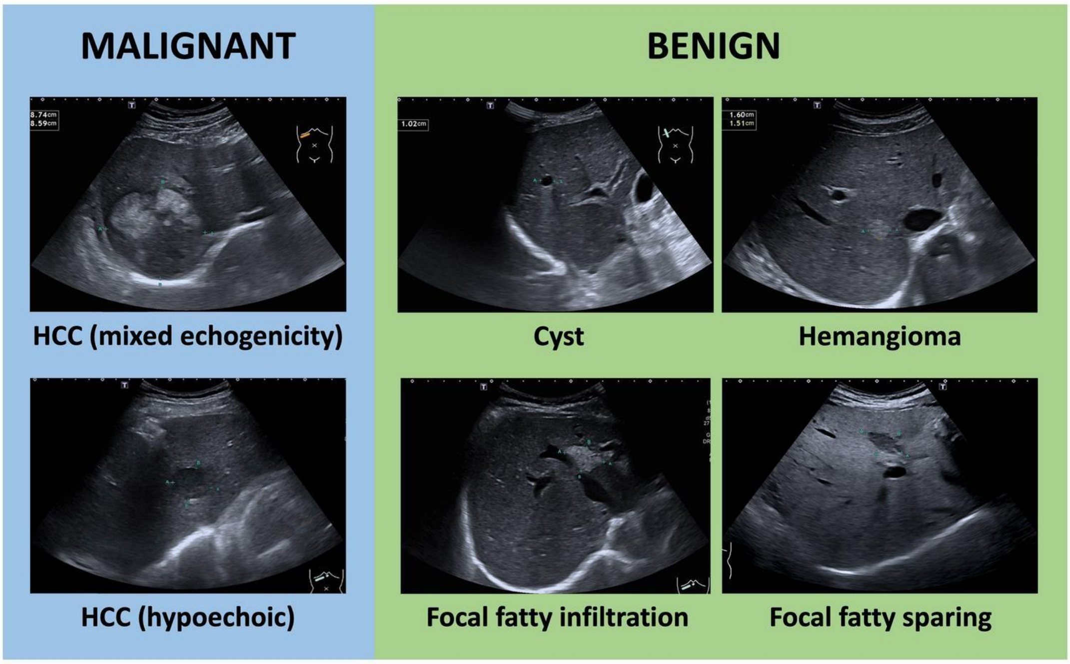


**Figure 2.5 Prevalence of Focal Liver Lesions (FLLs)**

Types of Benign FLLs Benign FLLs are more common than malignant ones, and they include a variety of lesion types that often do not require aggressive treatment:

- **Hepatic Hemangioma**: This is the most common type of benign liver lesion. Hemangiomas are typically small, asymptomatic, and often detected incidentally during imaging. These lesions consist of clusters of blood vessels and are usually benign, with no need for intervention unless they cause symptoms.

- **Focal Nodular Hyperplasia (FNH)**: FNH is a benign liver tumor characterized by a central scar visible on imaging, typically occurring in women. While this lesion is generally asymptomatic, it may require monitoring, especially in cases where the tumor size or appearance raises concerns.
- **Liver Cysts**: These are **fluid-filled sacs** within the liver that can be simple or complex. Simple liver cysts are often asymptomatic, but larger or complex cysts may require further investigation to ensure they are not associated with other liver conditions.
- **Focal Fat Sparing**: This condition involves areas of the liver where the fat content is lower compared to the surrounding tissue. These lesions are generally benign and reflect changes in liver metabolism or fatty infiltration, often seen in patients with certain metabolic conditions or liver diseases.

**Types of Malignant FLLs**

Malignant FLLs are less common but more concerning.

They include:

- **Hepatocellular Carcinoma (HCC)**: HCC is the most common form of primary liver cancer, often associated with cirrhosis and chronic liver diseases like hepatitis B or C. Early diagnosis through imaging and biopsy is critical for better treatment outcomes.

- **Cholangiocarcinoma (CCC)**: This cancer originates in the bile ducts within the liver and is less common than HCC. It is often diagnosed at a more advanced stage, making early detection through imaging vital for improving prognosis.

- **Liver Metastases**: These lesions occur when cancer from other parts of the body, such as the colon, lungs, or breast, spreads to the liver. Imaging plays a key role in identifying metastatic lesions early, allowing for the timely initiation of treatment.

# MATERIALS AND METHODS

## Source of Data

The study population consisted of patients who were referred to undergo sono-elastography at the Department of Radio-Diagnosis, KLE's Dr. Prabhakar Kore Hospital & MRC, Belagavi. These patients either presented with clinically suspected focal hepatic lesions or had incidental focal liver lesions detected on computed tomography (CT) or magnetic resonance imaging (MRI). The referral for sono-elastography was made to further diagnose, characterize, or confirm the existence of focal hepatic lesions initially suggested by other radiological or investigational findings.

## Study Design:

This investigation was performed as a **prospective, observational study**. All eligible patients meeting the inclusion criteria underwent a standardized assessment protocol, and data were systematically collected and analyzed.

## Study Period:

The study was conducted over a period of **one year**. During this time, consecutive patients who fulfilled the inclusion criteria were approached, explained the details of the study, and invited to participate

## Sample Size:

A total of **32** patients were included in the study. The sample size calculation was performed using the formula based on the area under the curve (AUC) prevalence approach:

n=(zα/2)2×v(AUC)d2,

where v(AUC) is the variance of the AUC, dd is the margin of error, and zα/2 is the critical value at a given significance level α\alpha.

From the article by Ludima Gerber, the reported AUC was 0.73 with a variance of 0.13945. For α=10%\alpha = 10\%, the corresponding zα/2 was 1.645, and the error margin (dd) was taken as 15% of the AUC (0.1095). Substituting these values:

n= (1.645)2×0.13945(0.1095)2

= 2.706×0.139450.01199

= 0.37735170.01199

= 31.47≈32.

Therefore, the final sample size was **32** patients with positive focal liver lesions.

### Sampling Technique

A **Universal Random Sampling** method was employed. All patients referred for sono-elastography who met the inclusion criteria during the study period were enrolled until the desired sample size was reached.

Inclusion and Exclusion Criteria

### Inclusion Criteria

1. Patients aged 18–90 years who were referred for sono-elastography with clinically suspected focal liver lesions.
2. Patients who had incidental focal liver lesions identified on other radiological examinations such as CT or MRI.

**Exclusion Criteria**

1. Patients without any focal liver lesions.
2. Patients with focal liver lesions measuring less than 5 mm in maximum diameter.
3. Patients who had undergone regional therapies (e.g., radiofrequency ablation) or systemic chemotherapy before the sono-elastography procedure, as these interventions could alter the characteristics of the lesion and potentially affect the diagnostic outcomes.

**Data Collection Procedure**

1. **Patient Referral and Registration**

All patients referred to the Department of Radiodiagnosis at KLE’s Dr. Prabhakar Kore Hospital & MRC, Belagavi, for evaluation of focal hepatic lesions by sono-elastography were initially registered. Each patient’s demographic information and clinical details were recorded in a pre- designed data collection format.

2. **Screening and Eligibility**

Eligible patients were those between 18 and 90 years of age who had suspicious or incidentally detected focal hepatic lesions on previous radiological investigations (CT or MRI). Patients who satisfied the inclusion criteria and did not meet any exclusion criteria were invited to participate in the study.

3. **Informed Consent**

Written informed consent was obtained from each patient prior to participation. The study details, including benefits, potential risks, and the nature of the sono-elastography procedure, were thoroughly explained. Only patients providing written, informed consent were included.

4. **Sono-elastography Examination**

Each participant underwent a standardized sono-elastography study using the MINDRAY-RESONA I9 ultrasound system. Patients were placed in an optimal position to visualize the liver (typically supine or left lateral decubitus). A low-frequency curvilinear transducer was employed to obtain images of the liver in conventional B-mode and to perform point or shear wave elastography assessments.

- **Lesion Localization and Measurement**: The liver was systematically scanned to locate the focal lesion. Each lesion's size, shape, and echogenicity were evaluated in conventional B-mode.

- **Elastographic Assessment**: Appropriate region-of-interest (ROI) boxes were placed over the target lesion, ensuring minimal motion artifact and high-quality elastographic signals. The system software automatically generated measurements of tissue stiffness in kilopascals (kPa).

- **Technical Parameters**: Multiple measurements (generally three to five) were taken per lesion, and the median or mean elastographic values were calculated, as per machine protocol.

- **Further Diagnostic Workup and Follow-up:** Triple phase computed tomography and biopsy or surgical resection was advised when clinically indicated. Patients who did not undergo immediate CT / histopathological evaluation were followed for up to **6 months** with repeat imaging to confirm the stability or progression of the lesion.

## 5. Data Recording

A structured questionnaire was used to capture relevant socio-demographic data (age, gender, etc.), clinical details (history of chronic liver disease, known malignancy, etc.), and the physical examination findings. Sono- elastography measurements and radiological interpretations were documented systematically for every participant.

## 1. Data Processing and Statistical Analysis

All collected data were entered into a Microsoft Excel spreadsheet. Quality checks were performed to ensure accuracy and completeness of the data. The data were then tabulated, and descriptive statistics (e.g., means, medians, standard deviations) were used to summarize continuous variables. Categorical variables were expressed as frequencies and percentages. Where relevant, comparative statistics (such as sensitivity, specificity, and receiver operating characteristic [ROC] curves) were planned to evaluate the diagnostic performance of sono- elastography. Anticipated Serious Adverse Events (SAE) or Adverse Events No serious adverse events were anticipated during the course of this study. The sono-elastography procedure is non-invasive and generally considered safe.

Investigations or Interventions During the Study Yes, the primary investigation used in this study was **sono-elastography** as a radiological tool to assess the stiffness of focal liver lesions. Additional interventions (e.g., biopsy) were performed only when clinically indicated or as part of standard diagnostic workup, and informed consent was obtained from each participant prior to any invasive procedure.

## Cost of Investigations and Interventions

No additional costs were imposed on the participants specifically for the purposes of this study. All investigations and procedures followed the routine clinical pathways of the hospital. Any incidental costs related to further evaluations or treatments (e.g., biopsy, surgery) were handled according to the existing hospital policies.

Budget Analysis

1. Searching of Literature: INR 2,000
2. Photocopy of Synopsis: INR 1,000
3. Proforma: INR 5,000
4. Informed Consent Forms: INR 2,000
5. Miscellaneous Expenses: INR 10,000

**Total** = INR 20,000

This budget included costs for literature review, questionnaire printing, consent forms, and other miscellaneous expenditures that facilitated the successful conduct of the study.

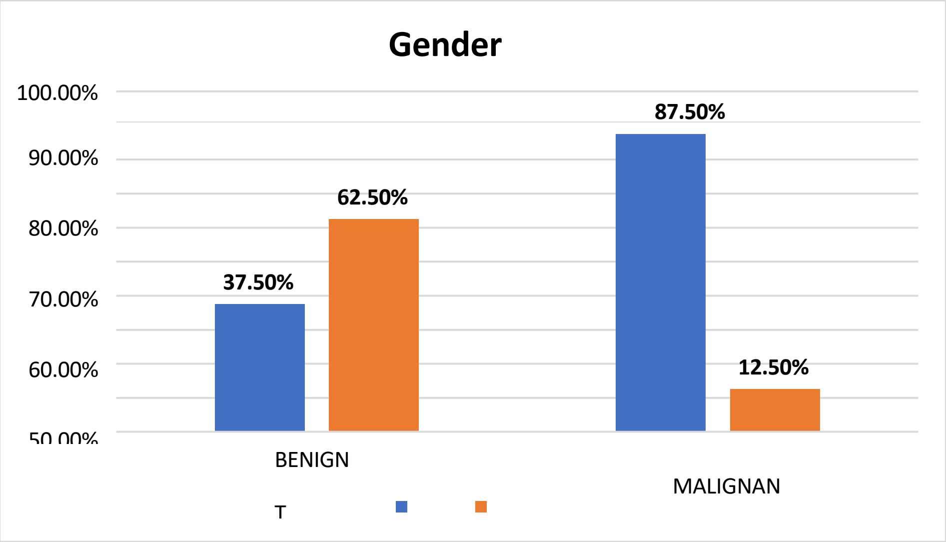
# RESULTS

This chapter presents a detailed analysis of the observational data collected over a one-year period in a hospital-based study. By examining demographic factors, lesion characteristics, and imaging parameters, the analysis aims to identify patterns that improve the differentiation between benign and malignant conditions. Special attention is given to the correlation between imaging-derived tissue stiffness measurements and triple phase CT findings, providing insights into its potential as a non-invasive diagnostic tool.

The synthesis of these findings not only quantifies the diagnostic performance of advanced imaging techniques but also identifies key predictors and thresholds that could guide clinical decision-making. Ultimately, this chapter sets the foundation for a deeper understanding of how quantitative imaging assessments contribute to lesion characterization, paving the way for improved diagnostic accuracy, patient management, and future research directions in clinical practice.

**Table 4.1: Gender Distribution Among Patients with Benign and Malignant Lesions**

| Gender | BENIGN | | MALIGNANT | |
|---|---|---|---|---|
| | **Frequency** | **Percent** | **Frequency** | **Percent** |
| Male | 3 | 37.5% | 21 | 87.5% |
| Female | 5 | 62.5% | 3 | 12.5% |
| Mean ± Std. Deviation= 1.25 ± 0.440 | | | | |

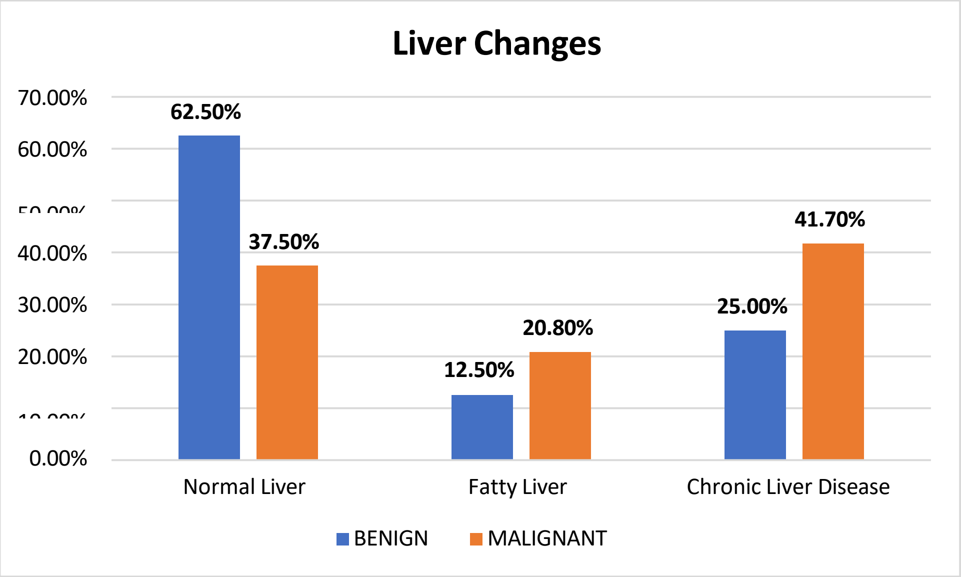


**Graph 4. 1: Gender-wise Distribution of Benign and Malignant Lesions**

The gender distribution shows a striking contrast with regard to the prevalence of benign versus malignant lesions. We note a preponderance of females (62.5%) for benign lesions, as opposed to males (37.5%). On the other hand, malignant lesions showed a predominance in males (87.5%) compared to the 12.5% females. The average gender distribution (1.25 ± 0.440) points to a significant male preponderance in malignant cases, suggesting a possible gender predisposition to malignancy in that studied population.

**Table 4.2 : Distribution of Liver Changes Among Patients with Benign and Malignant Lesions**

| Liver Changes | BENIGN | | MALIGNANT | |
|---|---|---|---|---|
| | **Frequency** | **Percent** | **Frequency** | **Percent** |
| Normal Liver | 5 | 62.5% | 9 | 37.5% |
| Fatty Liver | 1 | 12.5% | 5 | 20.8% |
| Chronic Liver Disease | 2 | 25.0% | 10 | 41.7% |
| Mean ± Std. Deviation= 1.94 ± 0.914 | | | | |

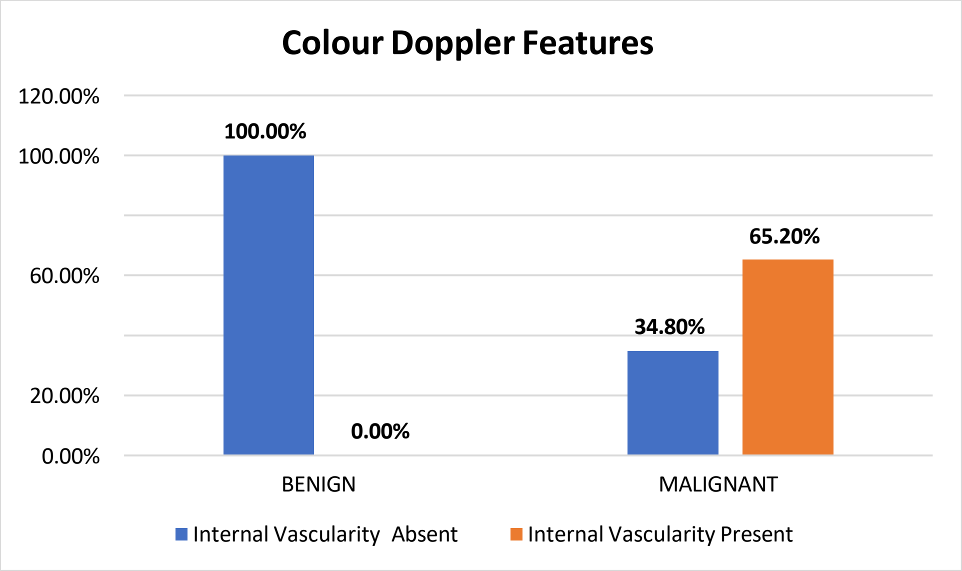


**Graph 4.2: Liver Changes in Patients with Benign and Malignant Lesions**

The distribution of liver changes in patients with benign and malignant lesions presents a different picture. A normal liver was noted in one of the benign cases (62.5%), while chronic liver disease (CLD) was present in 25.0% of these cases and fatty liver in 12.5%. In malignant cases, on the other hand, dominant liver abnormalities are often found, as 41.7% of the patients had CLD and 20.8% had fatty liver, while the normal liver condition was present in only 37.5% of cases. The average distribution of liver changes (1.94 ± 0.914), therefore, indicates a preponderance of malignant lesions among patients having existing liver disorders; and among these liver disorders what stood out was CLD, which might also represent a possible risk for the development of malignancy.

**Table 4.3: Distribution of Color Doppler Features in Benign and Malignant Lesions**

| Colour Doppler Features | BENIGN | | MALIGNANT | |
|---|---|---|---|---|
| | Frequency | Percent | Frequency | Percent |
| Internal Vascularity Absent | 9 | 100.0% | 8 | 34.8% |
| Internal Vascularity Present | 0 | 0.0% | 15 | 65.2% |
| Mean ± Std. Deviation= 1.72 ± 0.457 | | | | |



**Graph 3: Internal Vascularity Distribution in Benign and Malignant Lesions**

The Color Doppler analysis shows a clear distinction in vascularity patterns between benign and malignant liver lesions. All benign lesions (100%) lacked internal vascularity, indicating a low blood supply, which is typical for non-aggressive lesions. In contrast, 65.2% of malignant lesions exhibited internal vascularity, while 34.8% showed absent vascularity, suggesting variability in tumor perfusion due to factors like necrosis or fibrosis. The mean vascularity distribution (1.72 ± 0.457) highlights that while vascularity presence strongly suggests malignancy, its absence does not rule it out. This emphasizes the importance of using Color Doppler alongside other imaging techniques, such as shear wave elastography or contrast- enhanced imaging, for accurate differentiation. Overall, internal vascularity is a strong indicator of malignancy, supporting the role of Color Doppler ultrasound in liver lesion characterization and early detection of aggressive tumors.

**Table 4.4: Distribution of Laboratory Investigation Findings in Benign and Malignant Lesions**

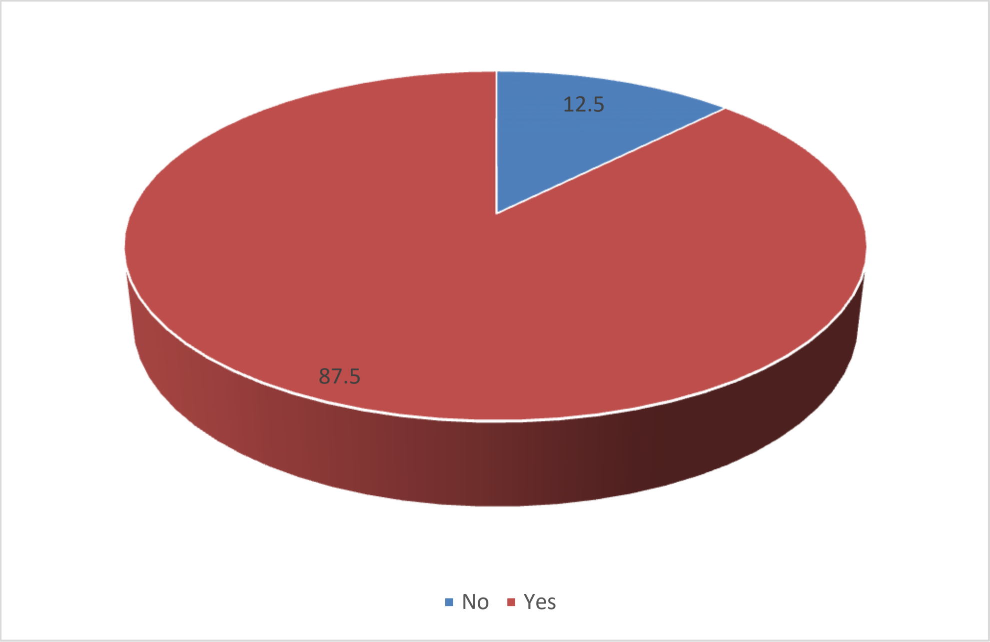
| Lab Investigations | BENIGN | | MALIGNANT | |
|---|---|---|---|---|
| | Frequency | Percent | Frequency | Percent |
| Normal | 8 | 100.0% | 10 | 41.7% |
| Abnormal | 0 | 0.0% | 14 | 58.3% |
| Mean ± Std. Deviation= 1.437 ± 0.504 | | | | |

**Figure 4: Comparison of Normal and Abnormal Laboratory Investigations in Benign and Malignant Lesions**

The laboratory investigation result distributions within the benign or malignant lesion cases exhibit a clear distinction. All benign cases (100.0%) had normal lab investigations, with none having abnormal investigations. In contrast, abnormal laboratory findings were observed in 58.3% of malignant cases, with only 41.7% having normal lab results. The mean lab investigation value indicates a strong link between abnormal lab results and malignancy. Abnormal laboratory parameters may serve as important predictors for malignancy and provide support for a diagnosis in the analysis of focal liver lesions.

**Table 4.5: Utilization of Confirmatory CT Scans in the Study Population**

| CONFIRMATORY CT ? | Frequency | Percent |
|---|---|---|
| No | 4 | 12.5 |
| Yes | 28 | 87.5 |

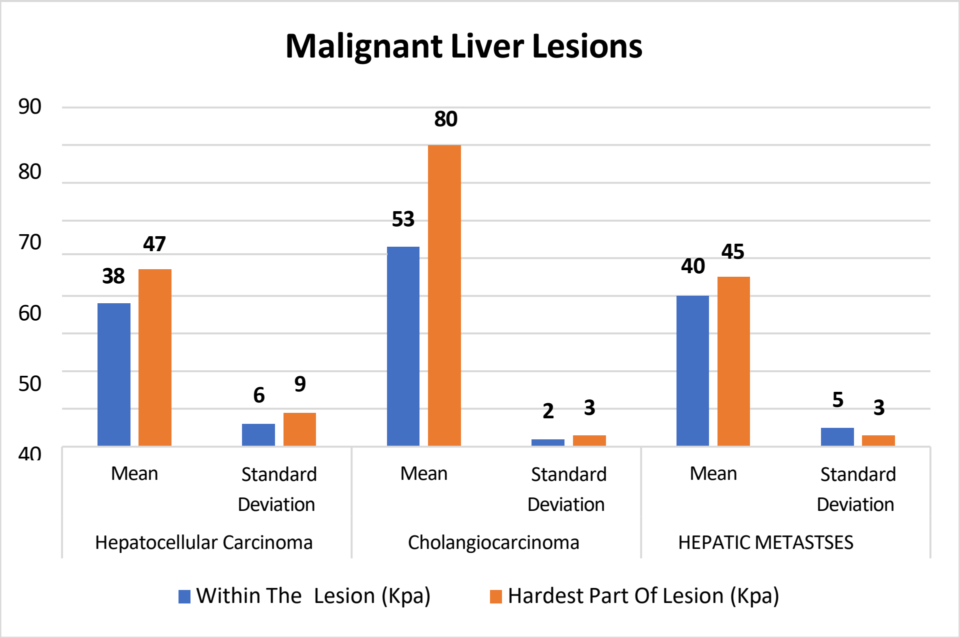


**Graph 4: Proportion of Patients Undergoing Confirmatory CT Scans**

The data on confirmatory CT scans reveals that the majority of patients (87.5%) underwent a confirmatory CT scan, while only 12.5% did not. This suggests that CT imaging plays a crucial role in further evaluating focal liver lesions, likely serving as a key diagnostic tool in differentiating between benign and malignant conditions. The high percentage of confirmatory CT scans highlights its significance in clinical decision-making and lesion characterization.

**Table 4.6: Shear Wave Elastography Stiffness Values in Different Malignant Liver Lesions**

| Malignant Liver Lesions | | Within The Lesion (Kpa) | Hardest Part Of Lesion (Kpa) |
|---|---|---|---|
| Hepatocellular Carcinoma | Frequency | 14 | 14 |
| | Mean | 38 | 47 |
| | Standard Deviation | 6 | 9 |
| Cholangiocarcinoma | Frequency | 3 | 3 |
| | Mean | 53 | 80 |
| | Standard Deviation | 2 | 3 |
| HEPATIC METASTSES | Frequency | 6 | 6 |
| | Mean | 40 | 45 |
| | Standard Deviation | 5 | 3 |

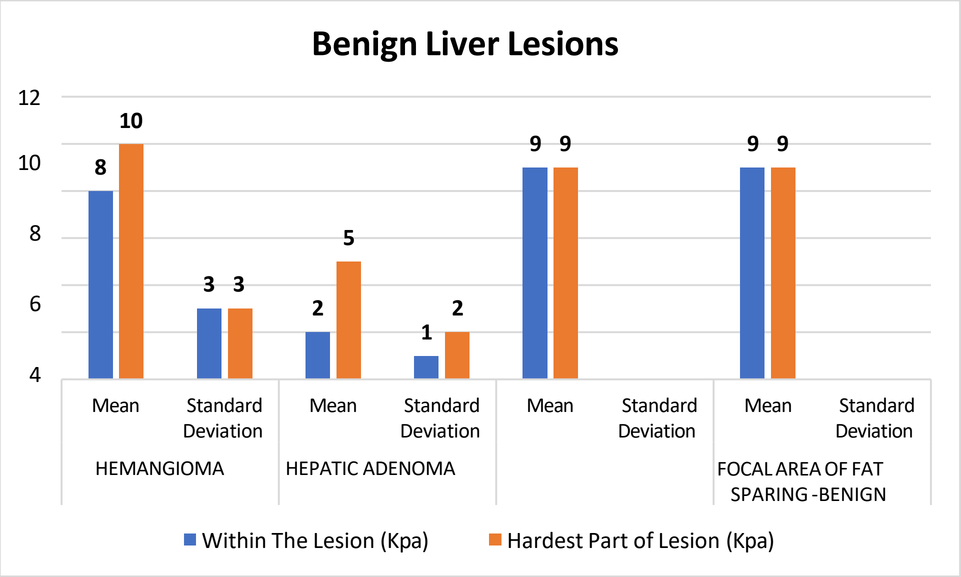


**Graph 5: Mean Stiffness Values Within and at the Hardest Part of Malignant Liver Lesions**

The evaluation of shear wave elastography (SWE) measurements within focal liver lesions and at their hardest part provides crucial insights into their stiffness characteristics across different malignant diagnoses. Among hepatocellular carcinoma (HCC) cases, the mean stiffness within the lesion was 38 kPa, increasing to 47 kPa at the hardest part, with respective standard deviations of 6 and 9. This suggests moderate stiffness variations within HCC, potentially indicating heterogeneous tissue composition. For cholangiocarcinoma, the mean stiffness was significantly higher at 53 kPa within the lesion and 80 kPa at the hardest part, with standard deviations of 2 and 3, respectively. The highest stiffness values among the malignancies suggest that cholangiocarcinoma is more fibrotic and rigid, which aligns with its aggressive nature and desmoplastic reaction. In hepatic metastases, the mean stiffness within the lesion was 40 kPa, and 45 kPa at the hardest part, with standard deviations of 5 and 3, respectively. While hepatic metastases exhibit stiffness levels comparable to HCC, the smaller variation between mean values within the lesion and the hardest part suggests a more uniform tissue composition. Overall, cholangiocarcinoma exhibited the highest stiffness values, while HCC and metastases showed moderately elevated stiffness with some degree of heterogeneity. These findings emphasize the potential role of SWE in differentiating between various malignant liver lesions based on stiffness characteristics, aiding in more precise diagnosis and treatment planning.

**Table 4.7: Shear Wave Elastography Stiffness Values in Benign Liver Lesions**

| **Benign Liver Lesions** | | Within The Lesion (Kpa) | Hardest Part of Lesion (Kpa) |
|---|---|---|---|
| HEMANGIOMA | Frequency | 5 | 5 |
| | Mean | 8 | 10 |
| | Standard Deviation | 3 | 3 |
| HEPATIC ADENOMA | Frequency | 2 | 2 |
| | Mean | 2 | 5 |
| | Standard Deviation | 1 | 2 |
| FNH | Frequency | 1 | 1 |
| | Mean | 9 | 9 |
| | Standard Deviation | | |
| FOCAL AREA OF FAT SPARING - BENIGN | Frequency | 1 | 1 |
| | Mean | 9 | 10 |
| | Standard Deviation | | |



**Graph 6: Mean Stiffness Values Within and at the Hardest Part of Benign Liver Lesions**

The analysis of shear wave elastography (SWE) stiffness values in various benign focal liver lesions provides valuable insights into their elasticity and tissue composition. Among hemangiomas, the mean stiffness within the lesion was 8 kPa, increasing slightly to 10 kPa at the hardest part, with a standard deviation of 3 in both cases. This relatively low stiffness aligns with the vascular nature of hemangiomas, which are typically soft and compressible. For hepatic adenomas, the mean stiffness was the lowest among the benign lesions, measuring 2 kPa within the lesion and 5 kPa at the hardest part, with standard deviations of 1 and 2, respectively. This finding supports the generally soft and non-fibrotic nature of hepatic adenomas. In focal nodular hyperplasia (FNH), the stiffness was 9 kPa both within the lesion and at the hardest part, indicating a homogeneous structure with moderate stiffness. Similarly, focal areas of fat sparing exhibited stiffness values of 9 kPa within the lesion and 10 kPa at the hardest part, further confirming their benign nature with limited variation in elasticity. Overall, these findings emphasize that benign liver lesions demonstrate lower stiffness values compared to malignant lesions, with hemangiomas, FNH, and fat-sparing areas showing slightly higher stiffness than hepatic adenomas. This highlights the potential of SWE in differentiating between benign and malignant focal liver lesions based on their stiffness characteristics.

**Table 4.8: Comparison of Shear Wave Elastography Stiffness Values Between Benign and Malignant Liver Lesions**

| | Final Diagnosis | n | Mean | SD | Test Statistic | p-value |
|---|---|---|---|---|---|---|
| Within The Lesion (kPa) | Benign Lesion | 9 | 7.06 | 3.36 | -10.393 | 0.000 |
| | Malignant | 23 | 40.59 | 6.81 | | |
| Hardest Part Of Lesion (kPa) | Benign Lesion | 9 | 8.59 | 2.83 | -9.546 | 0.000 |
| | Malignant | 23 | 50.74 | 13.52 | | |

The statistical analysis comparing lesion stiffness between benign and malignant lesions reveals significant differences in elasticity values, both within the lesion and at its hardest part.

The mean stiffness within benign lesions was 7.06 kPa (SD = 3.36), while malignant lesions exhibited a significantly higher mean stiffness of 40.59 kPa (SD = 6.81). This large discrepancy is reflected in the test statistic (-10.393) and a highly significant p-value (p = 0.000), indicating a strong statistical difference between the two groups. Similarly, when analyzing the hardest part of the lesion, benign lesions had a mean stiffness of 8.59 kPa (SD = 2.83), whereas malignant lesions showed a much higher mean stiffness of 50.74 kPa (SD = 13.52). The test statistic (-9.546) and p-value (p = 0.000) confirm the statistical significance of this difference. These results suggest that malignant lesions tend to be significantly stiffer than benign lesions, both overall and at their hardest points, reinforcing the potential clinical utility of elasticity measurements in distinguishing between benign and malignant lesions.

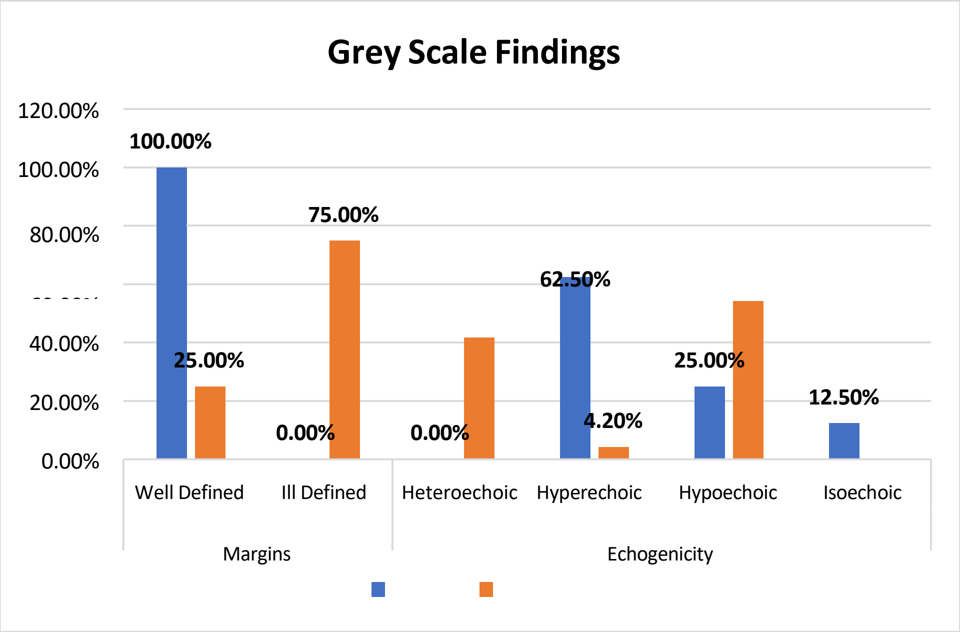
**Table 4.9: Descriptive Statistics of Shear Wave Elastography Stiffness Values in Liver Lesions**

| Variables | N | Mean | Std. Deviation | Median | Minimum | Maximum |
|---|---|---|---|---|---|---|
| Within the Lesion (kPa) | 32 | 31.16 | 16.45 | 37.45 | 1.4 | 55.40 |
| Hardest Part of Lesion (Kpa) | 32 | 38.89 | 22.42 | 43.35 | 3.4 | 82.00 |

The statistical analysis of lesion stiffness measured in kilopascals (kPa) reveals significant variability in the elastic properties within the lesion and at its hardest part. The mean stiffness within the lesion was 31.16 kPa (SD = 16.45), with a median value of 37.45 kPa, indicating that the central tendency is slightly skewed due to the variation in stiffness values. The minimum recorded stiffness within the lesion was 1.4 kPa, while the maximum reached 55.4 kPa, highlighting a broad range of lesion elasticity. In contrast, the hardest part of the lesion exhibited a higher mean stiffness of 38.89 kPa (SD = 22.42), with a median of 43.35 kPa, suggesting that the stiffest regions within lesions generally have higher elasticity values. The minimum hardness recorded in the stiffest region was 3.4 kPa, while the maximum stiffness peaked at 82.0 kPa, showing even greater variability. These findings indicate that lesions exhibit heterogeneous mechanical properties, with distinct differences between the overall lesion stiffness and its hardest regions, which may have clinical implications in diagnosing lesion severity, progression, or treatment response.

**Table 4.10: Grey-Scale Ultrasound Features in Benign and Malignant Liver Lesions**

| Grey Scale Findings | | Malignant | | | |
|---|---|---|---|---|---|
| | | Benign | | Malignant | |
| | | Frequency | Percent | Frequency | Percent |
| Margins | Well Defined | 8 | 100.0% | 6 | 25.0% |
| | Ill Defined | 0 | 0.0% | 18 | 75.0% |
| Echogenicity | Heteroechoic | 0 | 0.0% | 10 | 41.7% |
| | Hyperechoic | 5 | 62.5% | 1 | 4.2% |
| | Hypoechoic | 2 | 25.0% | 13 | 54.2% |
| | Isoechoic | 1 | 12.5% | 0 | 0.0% |



**Graph 7: Distribution of Margins and Echogenicity in Benign and Malignant Liver Lesions**

The grey-scale ultrasound findings reveal significant differences between benign and malignant liver lesions, particularly in terms of margins and echogenicity. Regarding margins, all benign lesions (100%) were well-defined, while only 25.0% of malignant lesions had well- defined margins. In contrast, the majority of malignant lesions (75.0%) exhibited ill-defined margins, which is a key imaging characteristic associated with aggressive tumor behavior and infiltrative growth patterns. In terms of echogenicity, benign lesions demonstrated a higher prevalence of hyperechoic appearance (62.5%), followed by hypoechoic (25.0%) and isoechoic (12.5%) patterns. Notably, none of the benign lesions appeared heteroechoic. On the other hand, malignant lesions predominantly exhibited hypoechoic echogenicity (54.2%), followed by heteroechoic (41.7%), while hyperechoic lesions were rare (4.2%), and no malignant lesions were isoechoic. These findings indicate that ill-defined margins and hypoechoic or heteroechoic echogenicity are strongly associated with malignancy, whereas well-defined margins and hyperechoic patterns are more common in benign lesions. These characteristics can serve as key imaging markers in differentiating between benign and malignant liver lesions, aiding in more accurate diagnostic interpretation and clinical decision-making.

**Table 4.11: Correlation Between Stiffness Within the Lesion and at the Hardest Part**

| **Correlations** | | | |
|---|---|---|---|
| | | **Within the Lesion (kPa)** | **Hardest Part of Lesion (kPa)** |
| **Within The Lesion (kPa)** | Pearson Correlation | 1 | .961** |
| | Sig. (2-tailed) | | .000 |
| | N | 32 | 32 |
| **Hardest Part Of Lesion (kPa)** | Pearson Correlation | .961** | 1 |
| | Sig. (2-tailed) | .000 | |
| | N | 32 | 32 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | |

The correlation analysis between shear wave elastography (SWE) stiffness values within the lesion and at its hardest part reveals a strong positive relationship. The Pearson correlation coefficient ($r = 0.961$, $p < 0.001$) indicates a highly significant correlation between the two measurements, suggesting that lesions with higher stiffness within the lesion also tend to have higher stiffness at their hardest part. Since the p-value is 0.000, this relationship is statistically significant at the 0.01 level, meaning that the likelihood of this correlation occurring by chance is extremely low. This strong association implies that stiffness measurements within the lesion can reliably predict the stiffness at the hardest part, reinforcing the consistency and reliability of SWE as a diagnostic tool. Clinically, this correlation suggests that SWE can provide consistent and reproducible stiffness measurements, which could be useful for lesion characterization, monitoring disease progression, and guiding therapeutic decisions. The results further support the potential of SWE in differentiating between benign and malignant lesions, as higher stiffness values are typically associated with malignancy.

**Table 4.12: Correlation of Shear Wave Elastography Stiffness Values with Grey-Scale and Doppler Ultrasound Features**

| Correlations | | | | | | |
|---|---|---|---|---|---|---|
| | | Within The Lesion (kPa) | Hardest Part of Lesion (kPa) | Margins | Echogenicity | Colour Doppler Features |
| Within The Lesion (Kpa) | Pearson Correlation | 1 | .961** | .771** | -.202 | -.931** |
| | Sig. (2- tailed) | | .000 | .000 | .267 | .000 |
| | N | 32 | 32 | 32 | 32 | 32 |
| Hardest Part of Lesion (kPa) | Pearson Correlation | .961** | 1 | .705** | -.236 | -.859** |
| | Sig. (2- tailed) | .000 | | .000 | .194 | .000 |
| | N | 32 | 32 | 32 | 32 | 32 |
| Margins | Pearson Correlation | .771** | .705** | 1 | -.132 | -.709** |
| | Sig. (2- tailed) | .000 | .000 | | .472 | .000 |
| | N | 32 | 32 | 32 | 32 | 32 |
| Echogenicity | Pearson Correlation | -.202 | -.236 | -.132 | 1 | .227 |
| | Sig. (2-tailed) | .267 | .194 | .472 | | .211 |
| | N | 32 | 32 | 32 | 32 | 32 |
| Colour Doppler Features | Pearson Correlation | -.931** | -.859** | -.709** | .227 | 1 |
| | Sig. (2- tailed) | .000 | .000 | .000 | .211 | |
| | N | 32 | 32 | 32 | 32 | 32 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | | | | |

The correlation analysis between shear wave elastography (SWE) stiffness values and grey- scale and Doppler ultrasound features highlights significant relationships that aid in liver lesion characterization. A strong positive correlation ($r = 0.961$, $p < 0.001$) exists between stiffness within the lesion and at its hardest part, reinforcing the consistency and reliability of SWE measurements. Additionally, higher stiffness values correlate significantly with ill-defined margins ($r = 0.771$, $p < 0.001$), suggesting that malignant lesions tend to have less well-defined borders. However, echogenicity does not show a significant correlation with stiffness ($p > 0.05$), indicating that echogenicity alone may not be a decisive predictor of lesion stiffness. Notably, a strong negative correlation is observed between stiffness and vascularity on color Doppler ($r = -0.931$, $p < 0.001$ for stiffness within the lesion; $r = -0.859$, $p < 0.001$ for the hardest part), suggesting that high-stiffness lesions, which are more likely to be malignant, tend to have reduced or absent vascularity. These findings emphasize that SWE is a valuable diagnostic tool, as malignant lesions typically exhibit higher stiffness, ill-defined margins, and lower vascularity, distinguishing them from benign counterparts. The study emphasises the role of SWE in improving diagnostic accuracy in focal liver lesions over traditional grey-scale and Doppler ultrasound findings.

# DISCUSSION

## 1. Introduction

The evaluation of liver lesions through multiple diagnostic modalities, including gender distribution, liver changes, Doppler ultrasound, laboratory investigations, confirmatory CT scans, and shear wave elastography (SWE), provides valuable insights into the differentiation between benign and malignant cases. This section presents the key findings, comparing them with existing literature and discussing their clinical implications for diagnosing and managing focal liver lesions.

## 2. Gender Distribution and Malignancy Risk

The gender-wise distribution of benign and malignant liver lesions revealed a significant male preponderance in malignant cases (87.5%), while benign lesions were more frequent in females (62.5%). The mean gender distribution (1.25 ± 0.440) supports prior studies that indicate a higher risk of liver malignancies in males, possibly due to higher exposure to risk factors like alcohol consumption, chronic hepatitis infections, and cirrhoss. This finding is consistent with research by Younossi et al. (2019), which reported that male patients exhibit a greater likelihood of developing hepatocellular carcinoma (HCC) due to hormonal and lifestyle factors.

## 3. Liver Changes and Their Association with Malignancy

The assessment of liver abnormalities in patients with benign and malignant lesions showed that chronic liver disease (CLD) was present in 41.7% of malignant cases, compared to only 25% in benign cases. Additionally, fatty liver was found in 20.8% of malignant cases, reinforcing the link between non- alcoholic fatty liver disease (NAFLD) and hepatocarcinogenesis. The mean liver change distribution

(1.94 ± 0.914) suggests that underlying liver pathology significantly influences malignancy risk. These findings align with those of Dyson et al. (2014), who identified CLD as a major risk factor for liver malignancies, particularly HCC.

### 4. Doppler Ultrasound and Internal Vascularity

The Color Doppler ultrasound analysis revealed a striking difference between benign and malignant lesions in terms of vascularity patterns. While 100% of benign lesions lacked internal vascularity, 65.2% of malignant lesions showed significant internal vascularity, reinforcing the importance of Doppler ultrasound in malignancy detection. The mean vascularity distribution (1.72 ± 0.457) suggests that internal vascularity is a strong predictor of malignancy, although its absence does not rule out cancer. These results are supported by Rimola et al. (2014), who emphasized the role of Doppler ultrasound in detecting neovascularization in HCC and metastatic liver lesions.

### 5. Laboratory Investigations and Malignancy Correlation

A significant difference was observed in laboratory investigations, where all benign cases (100%) had normal lab values, whereas 58.3% of malignant cases exhibited abnormal laboratory findings. The mean lab investigation value (1.437 ± 0.504) highlights the diagnostic importance of abnormal lab parameters, particularly elevated alpha-fetoprotein (AFP) levels and liver function test abnormalities, in distinguishing malignancy. These findings align with the work of Marrero et al. (2018), which demonstrated that elevated AFP and abnormal liver enzyme levels are highly suggestive of HCC and metastatic liver malignancies.

### a. Confirmatory CT Scans for Diagnosis

The study found that 87.5% of patients underwent confirmatory CT scans, suggesting that CT imaging is essential in the diagnostic process of liver lesions. This high utilization aligns with global clinical guidelines recommending multiphasic contrast-enhanced CT for liver malignancy diagnosis (Forner et al., 2018). The role of CT in characterizing lesion morphology, enhancement patterns, and vascular supply is well-established in the literature.

## 6. Shear Wave Elastography and Lesion Stiffness

The shear wave elastography (SWE) analysis of malignant lesions revealed that cholangiocarcinoma exhibited the highest stiffness (53 kPa within the lesion, 80 kPa at its hardest part), followed by hepatic metastases (40 kPa and 45 kPa) and HCC (38 kPa and 47 kPa). These values indicate a higher fibrotic content and rigidity in cholangiocarcinoma, which is consistent with prior research by Friedrich-Rust et al. (2012), demonstrating that stiffness values increase in malignant lesions due to fibrosis and increased cellular density.

In contrast, benign lesions demonstrated significantly lower stiffness values, with hepatic adenomas showing the lowest stiffness (2 kPa within the lesion, 5 kPa at the hardest part), while hemangiomas and focal nodular hyperplasia (FNH) exhibited slightly higher stiffness values (8–10 kPa). The ability of SWE to differentiate between benign and malignant lesions suggests its potential as a non- invasive diagnostic tool, reducing unnecessary biopsies in clinical settings.

## 7. Statistical Comparison of Stiffness Between Benign and Malignant Lesions

The statistical analysis confirmed a significant difference in stiffness values between benign and malignant lesions. The mean stiffness within benign lesions was 7.06 kPa, compared to 40.59 kPa in malignant lesions ($p < 0.001$). Similarly, at the hardest part, malignant lesions had a significantly higher stiffness (50.74 kPa) compared to benign lesions (8.59 kPa). These findings support previous studies by Guo et al. (2020), emphasizing that higher stiffness values are strongly associated with malignant pathology, aiding in lesion differentiation.

## 8. Grey-Scale Ultrasound Features and Malignancy Indicators

The grey-scale ultrasound analysis revealed that 75% of malignant lesions had ill-defined margins, while all benign lesions exhibited well-defined borders. Additionally, hypoechoic or heteroechoic echogenicity was more common in malignant lesions (54.2% and 41.7%, respectively), while benign lesions predominantly appeared hyperechoic (62.5%). These findings align with studies by El-Serag & Kanwal (2014), which concluded that irregular margins and heterogeneous echogenicity are reliable indicators of malignancy.

## 9. Correlation Between SWE Stiffness and Other Imaging Parameters

A strong correlation ($r = 0.961$, $p < 0.001$) was found between SWE stiffness values within the lesion and at its hardest part, suggesting that stiffness is a consistent marker for malignancy. Additionally, SWE stiffness correlated positively with ill-defined margins ($r = 0.771$, $p < 0.001$) and negatively with internal vascularity on

Color Doppler ($r = -0.931$, $p < 0.001$), reinforcing the role of elastography in predicting tumor aggressiveness.

### 10. Discussion

The findings of this study highlight the critical role of integrating multiple imaging modalities, including Shear Wave Elastography (SWE), Color Doppler, and grey- scale ultrasound, in the characterization of liver lesions. The combination of these imaging techniques offers a more comprehensive diagnostic approach, reinforcing their collective utility in distinguishing between benign and malignant liver lesions. Given the inherent complexity of liver pathology, a multi-modal imaging strategy is crucial in ensuring accurate diagnosis, effective treatment planning, and improved patient outcomes. A key takeaway from the study is the differentiation of liver lesions based on various imaging parameters. Malignant lesions consistently exhibited higher stiffness, ill-defined margins, increased vascularity, and abnormal laboratory findings, whereas benign lesions were characterized by lower stiffness, well-defined margins, and normal vascularity.

The significant disparity in these attributes underscores the importance of utilizing complementary imaging techniques to establish a precise diagnosis. Among these, SWE demonstrated its effectiveness by quantitatively assessing lesion stiffness, a major determinant in distinguishing between benign and malignant tumors. This parameter, when analyzed in conjunction with Doppler vascularity assessment and grey-scale ultrasound features, enhances diagnostic accuracy by providing multiple layers of pathological insight. The statistical correlation between SWE stiffness and other imaging features, such as vascularity, lesion margins, and echogenicity, further substantiates its potential as a reliable diagnostic tool. The observed association between increased lesion stiffness and malignancy supports the hypothesis that malignant liver lesions exhibit greater fibrotic content and cellular density. This correlation is particularly useful in early tumor detection, as it enables the identification of high-risk lesions before they progress into more advanced stages. Additionally, the study revealed that chronic liver disease (CLD) and fatty liver were more prevalent in malignant cases, reinforcing the well-documented link between underlying liver pathology and an increased risk of malignancy. This finding is consistent with prior research that highlights the role of chronic hepatic conditions in predisposing individuals to liver cancer, thereby emphasizing the need for vigilant monitoring of high-risk patients.

Doppler ultrasound emerged as a critical imaging modality in the assessment of vascularity within liver lesions. The study found that while all benign lesions lacked internal vascularity, a significant proportion (65.2%) of malignant lesions exhibited marked vascularization.

This aligns with global literature emphasizing the role of neovascularization in hepatocellular carcinoma (HCC) and metastatic liver tumors. Since neovascularization is a hallmark of tumor growth and malignancy, Doppler ultrasound serves as a valuable tool for detecting abnormal blood flow patterns associated with cancerous lesions. The ability to visualize internal vascularity provides radiologists and clinicians with essential information to differentiate between benign and malignant lesions, particularly in cases where grey-scale ultrasound findings are inconclusive. In addition to imaging techniques, laboratory investigations played a crucial role in liver lesion characterization. The study reported that all benign cases exhibited normal laboratory values, while a substantial proportion of malignant cases presented with abnormal biochemical parameters, notably elevated alpha-fetoprotein

(AFP) levels and liver function test abnormalities. These findings align with established diagnostic protocols, as AFP is widely recognized as a key tumor marker for hepatocellular carcinoma. Abnormal liver function tests further corroborate the presence of malignancy, particularly in the context of underlying liver disease. The combination of imaging findings and laboratory markers enhances diagnostic accuracy, allowing for a more comprehensive evaluation of liver lesions.

The study also reaffirmed the importance of confirmatory CT scans in liver lesion characterization. The high percentage (87.5%) of patients who underwent CT imaging reflects the global clinical consensus on the necessity of multiphasic contrast-enhanced CT in diagnosing liver malignancies.

CT imaging provides critical insights into lesion morphology, enhancement patterns, and vascular supply, supplementing the findings obtained from ultrasound-based techniques. The integration of CT imaging with SWE, Doppler ultrasound, and grey- scale imaging creates a robust diagnostic framework, enabling clinicians to make well-informed decisions regarding patient management. SWE analysis provided crucial insights into lesion stiffness, a key distinguishing feature between benign and malignant liver tumors. The study reported that the highest stiffness values were observed in cholangiocarcinoma, followed by hepatic metastases and hepatocellular carcinoma. This pattern suggests that malignant lesions possess higher fibrotic content and cellular density, making stiffness a strong predictor of malignancy. In contrast, benign lesions exhibited significantly lower stiffness values, with hepatic adenomas demonstrating the lowest stiffness among all benign cases. These findings reinforce the growing recognition of SWE as a non-invasive alternative to biopsy in the differentiation of focal liver lesions. The ability to quantify tissue stiffness using SWE enhances diagnostic confidence and reduces the need for invasive procedures, thereby improving patient comfort and reducing healthcare costs.

Statistical analysis further validated the significance of stiffness as a diagnostic marker. The study found that malignant lesions exhibited a mean stiffness of 40.59 kPa within the lesion and 50.74 kPa at its hardest part, whereas benign lesions had substantially lower values of 7.06 kPa and 8.59 kPa, respectively. The strong statistical significance ($p < 0.001$) underscores the robustness of SWE as a quantitative diagnostic tool.

Furthermore, SWE stiffness was found to correlate positively with ill-defined lesion margins and negatively with internal vascularity, further reinforcing its predictive value in assessing tumor aggressiveness. This correlation provides additional diagnostic insight, as ill-defined margins are often associated with infiltrative tumor growth, while a lack of internal vascularity in highly stiff lesions suggests advanced fibrosis or necrotic tumor regions. Grey-scale ultrasound findings contributed significantly to the characterization of liver lesions. The study observed that 75% of malignant lesions exhibited ill-defined margins and either hypoechoic or heteroechoic echogenicity, whereas benign lesions were predominantly hyperechoic with well- defined margins. These findings align with existing literature indicating that irregular margins and heterogeneous echogenicity are hallmark features of malignancy. The presence of hypoechoic or heteroechoic echogenicity in malignant lesions can be attributed to the varying cellular composition and necrotic regions within tumors, whereas the well-defined and hyperechoic appearance of benign lesions is reflective of their more uniform structure and lower cellular density.

The clinical implications of these findings are profound. Given the non-invasive nature of SWE, it presents a promising diagnostic tool that could significantly reduce the need for invasive biopsies while maintaining high diagnostic accuracy. The integration of AI-based image analysis with SWE could further enhance diagnostic precision by enabling automated lesion classification and risk stratification. AI-driven algorithms can analyze imaging patterns more efficiently than manual interpretation, potentially leading to earlier detection and improved prognostic assessment.

Future research should focus on longitudinal studies to evaluate the prognostic value of SWE in monitoring tumor progression and treatment response. Additionally, expanding the role of AI in liver lesion characterization could open new avenues for personalized medicine, where treatment decisions are tailored based on quantitative imaging biomarkers. In conclusion, this study underscores the clinical significance of Shear Wave Elastography in differentiating liver lesions, providing a reliable, non-invasive, and cost-effective diagnostic alternative. By combining SWE with Doppler ultrasound, grey-scale imaging, and laboratory investigations, clinicians can achieve a comprehensive, multi-modal assessment of liver lesions. This approach facilitates early detection, accurate diagnosis, and effective treatment planning, ultimately improving patient outcomes. The findings of this study align with global guidelines advocating for non-invasive imaging modalities in liver lesion evaluation, reinforcing the growing role of advanced ultrasound techniques in hepatology. As imaging technology continues to evolve, the integration of SWE into routine clinical practice holds the potential to revolutionize liver lesion assessment, paving the way for more efficient, precise, and patient-friendly diagnostic strategies.

# CONCLUSION AND RECOMMENDATION

## Conclusion

This study comprehensively analyzed the diagnostic accuracy of shear wave elastography (SWE) in differentiating benign and malignant focal liver lesions compared to conventional imaging techniques, such as grey-scale ultrasound and Color Doppler features. The findings demonstrate that SWE values are significantly more reliable and consistent in assessing lesion stiffness, making it a superior diagnostic tool for liver lesion characterization.

The results indicated that malignant lesions exhibit significantly higher stiffness values, with a mean stiffness of 40.59 kPa (SD = 6.81) within the lesion and 50.74 kPa (SD = 13.52) at the hardest part. In contrast, benign lesions displayed much lower stiffness values, with mean values of 7.06 kPa (SD = 3.36) within the lesion and 8.59 kPa (SD = 2.83) at the hardest part. The strong statistical significance ($p < 0.001$) further reinforces that SWE is highly effective in distinguishing between benign and malignant lesions based on tissue stiffness.

The correlation analysis between SWE values and other imaging features highlighted that stiffness measurements were strongly associated with malignancy indicators, such as ill-defined margins and reduced vascularity on Color Doppler. While grey-scale ultrasound and Color Doppler features provided useful insights, they lacked the diagnostic precision offered by SWE. Ill-defined margins and increased vascularity were seen in some benign lesions, making conventional imaging less specific in ruling out malignancy. In contrast, SWE demonstrated a consistent correlation with lesion pathology, allowing for higher diagnostic confidence and reducing the need for unnecessary biopsies.

These findings emphasize that SWE is a significantly accurate tool for differentiating benign and malignant focal liver lesions, surpassing the reliability of grey-scale ultrasound and Doppler ultrasound. The integration of SWE in routine liver lesion evaluation can enhance early detection, guide clinical decision-making, and optimize treatment strategies.

## RECOMMENDATIONS

1. **Incorporation of SWE in Routine Liver Imaging**
    - SWE should be routinely integrated into liver imaging protocols for early differentiation of benign and malignant lesions.
    - Diagnostic workflows should prioritize SWE alongside grey-scale and Doppler ultrasound to improve the accuracy of non-invasive liver lesion characterization.
2. **Training and Capacity Building for Clinicians**
    - Radiologists and hepatologists should receive specialized training in interpreting SWE values to maximize its diagnostic potential.
    - Workshops and continuing medical education (CME) programs should be conducted to increase familiarity with SWE technology among healthcare providers.
3. **Use of SWE to Reduce Unnecessary Biopsies**
    - Given its high diagnostic accuracy, SWE should be considered a first-line screening tool to reduce the need for invasive procedures such as biopsies, especially in cases where malignancy risk is low.
    - SWE can be used as an adjunct to multiphasic contrast-enhanced imaging for comprehensive lesion evaluation.

4. **Further Research on SWE Cutoff Values for Malignancy**
   - Future studies should establish standardized stiffness cutoff values for differentiating various liver malignancies, such as hepatocellular carcinoma (HCC), cholangiocarcinoma, and hepatic metastases.
   - Multicenter trials should be conducted to validate the optimal kPa threshold for distinguishing benign from malignant lesions across diverse patient populations.
5. **Combining SWE with AI-Based Diagnostic Systems**
   - Artificial intelligence (AI) and machine learning models should be developed to enhance the accuracy of SWE interpretation, reducing subjectivity in stiffness measurements.
   - AI-assisted SWE evaluation can help predict tumor progression, assess treatment response, and improve early detection strategies.
6. **Expansion of SWE Technology in Low-Resource Settings**
   - Given the non-invasive and cost-effective nature of SWE, efforts should be made to expand its accessibility in low-resource settings where advanced imaging modalities like CT and MRI are limited.
   - Portable SWE devices should be developed to facilitate point-of-care liver lesion evaluation in primary healthcare centers.
7. **Longitudinal Studies to Assess Prognostic Value of SWE**
   - Future research should focus on long-term follow-up of liver lesions evaluated with SWE to determine its role in predicting malignancy progression and treatment response.
   - Studies should investigate how SWE stiffness values change over time in patients undergoing treatment for liver malignancies.

## Final Thoughts

This study establishes shear wave elastography (SWE) as a superior and highly reliable imaging modality for distinguishing benign and malignant focal liver lesions. Compared to grey-scale ultrasound and Doppler imaging, SWE demonstrated significantly higher diagnostic accuracy, strong statistical significance, and a clear correlation with malignancy indicators. By integrating SWE into standard clinical practice, unnecessary biopsies can be reduced, early tumor detection can be improved, and more precise treatment planning can be facilitated.

Future advancements in SWE-based liver lesion evaluation, AI integration, and widespread accessibility in resource-limited settings will further enhance its role as a non-invasive, accurate, and essential diagnostic tool in hepatology.

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# ANNEXURES

## ANNEXURE – I - INFORMED CONSENT FORM

### TITLE OF THE PROJECT/STUDY: 2D SHEAR WAVE ELASTOGRAPHY TO EVALUATE FOCAL LIVER LESIONS”-ONE YEAR HOSPITAL BASED OBSERVATIONAL STUDY.’

**Name of Student/Principal Investigator: ________**

**Name of Guide/Co Investigators: __________________**

**Introduction:**

Focal liver lesions are quite common. These lesions can be classified as benign or malignant.Early diagnosis of malignant liver lesions helps in improving the treatment outcomes of the patients.

Modalities used commonly for diagnosing these lesions used are contrast enhanced ultrasonography, computed, tomography magnetic resonance imaging and biopsy

All these procedures are associated with complications as well.

Ultrasound elastography is a newer modality which is safer with less radiation exposure and is a non-invasive procedure, with cost similar to a biopsy and helps in differentiating the benign and malignant lesions.

**Explanation of procedure:**

After proper informed, written consent, patients coming for liver ultrasonography and fitting the inclusion criteria will be selected.

Patients will fill the pre-designed questionnaire.

Findings will be noted and grading of the lesion will be done by sonographic elastography with MINDRAY RESONA I9.

The lesion will be seen on elastography and findings will be noted.

**Withdrawal from participation in the study:**

Participation in this study is voluntary. You will be free to decide whether to participate in this study or continue participation once enrolled. In case you decide to withdraw you are free to do it. However please inform the decision to the principal investigator

**Possible benefits from participating in the study:**

You will / will not get any benefits by participating in this study. The data gathered will help population at large.

**Possible risks from participating in the study:** There are no risks involved in participating in the study

**Privacy and confidentiality:** The information collected from you will be coded, to prevent any person to identify you. Your identity will never be revealed. The data collected from you will be kept confidential and only processed or aggregated data will be used for publication.

**Financial incentives:** You will not receive any payment for participating in this study.

**Cost of investigations** done during the course of study will be paid by the **Participant.**

**Authorization for publication of aggregated data:** Results obtained after processing of the aggregated data will be published for scientific purpose and or presented to scientific groups.

However, your identity will never be revealed.

**Questions:**

If you have any question or complaints with regard to your right as study participant you may contact Dr Harsha Hegde, Chairperson, Ethical committee of JNMC, 0831-2473777 Extension 4052.

**Legal rights:** By signing this consent form, we are not waving any of your legal rights

## CONSENT STATEMENT

I am making a voluntary decision to participate in the study **"UTILITY OF 2D SHEAR WAVE ELASTOGRAPHY TO EVALUATE FOCAL LIVER LESIONS"-ONE YEAR HOSPITAL BASED OBSERVATIONAL STUDY** My signature below indicates that I have decided to participate and I have read the information provided above or the information provided above has been read to me in the language that I understand best. I was given the opportunity to ask questions and that they have been answered to my satisfaction.

Name of the participant:

Signature or left thumb impression of the participant:

Name of the witness:

Signature or left thumb impression of the witness:

Name of the investigator:

Signature of the investigator:

## ANNEXURE – II - PROFORMA

## 2D SHEAR WAVE ELASTOGRAPHY TO EVALUATE FOCAL LIVER LESIONS

**PROFORMA**

**NAME:**

**PATIENT ID:**

**AGE:**

**SEX:**

**CLINICAL COMPLAINTS:**

**LAB INVESTIGATIONS:**

**LIVER CHANGES IN USG**

**NORMAL:**

**FATTY:**

**FEATURES OF CHRONIC LIVER DISEASE:**

**GRAY SCALE AND COLOUR DOPPLER FINDINGS OF THE LESION**

**MARGINS:**

**ECHOGENICITY:**

**SIZE**

**VASCULARITY**

**SHEAR WAVE ELASTOGRPHY VALUES**

**WITHIN THE LESION:**

**HARDEST PART OF THE LESION:**

**FOLLOW UP/CONFIRMATORY COMPUTED TOMOGRAPHY:**

# ANNEXURE III: PHOTOGRAPHS

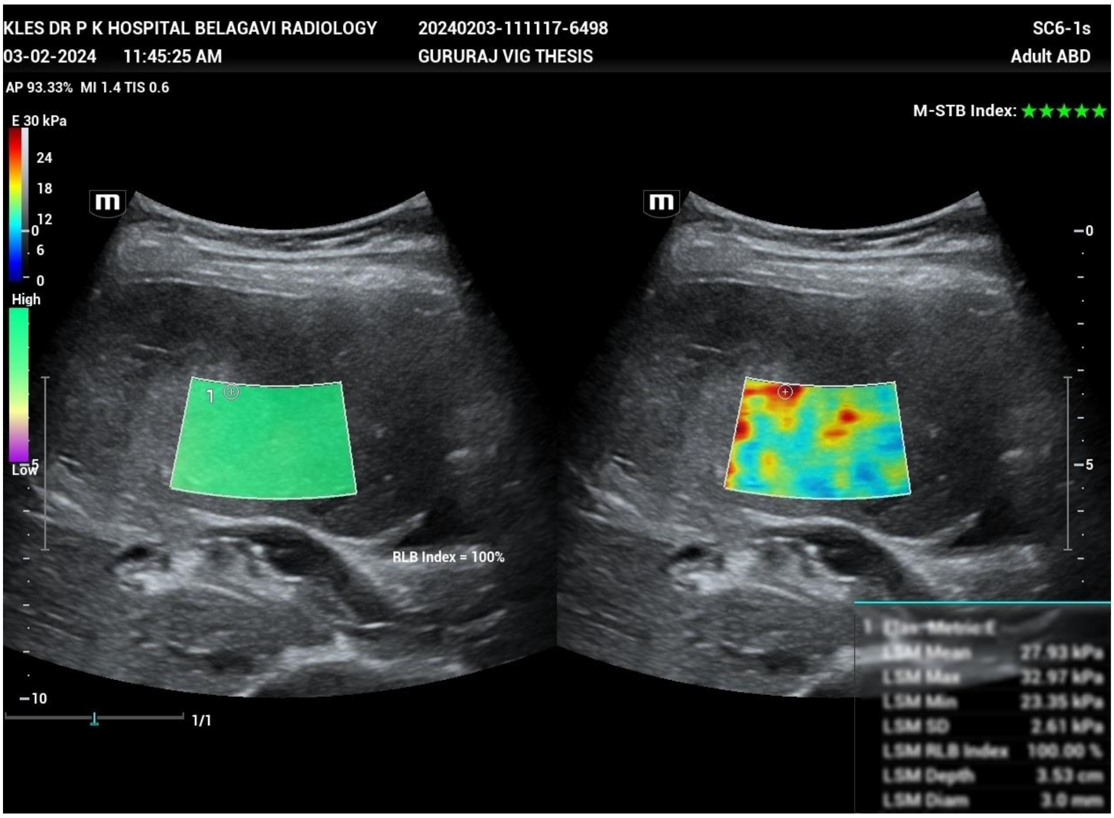


**Image 1: Showing a case of hepatocellular carcinoma with the mean stiffness values of 37.2 kPa and the hardest part of the lesion shows mean stiffness values of 47.6 kPa**

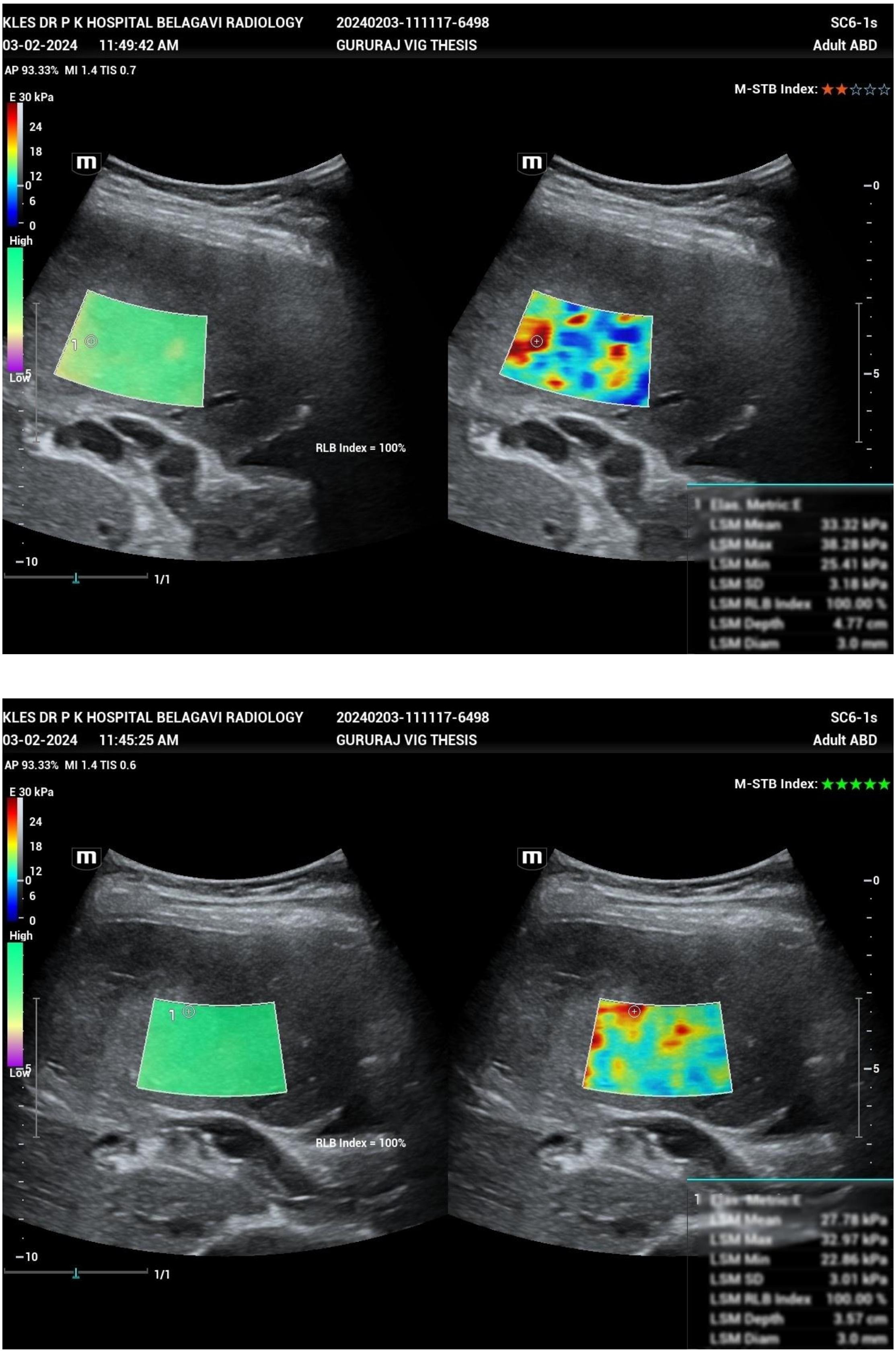
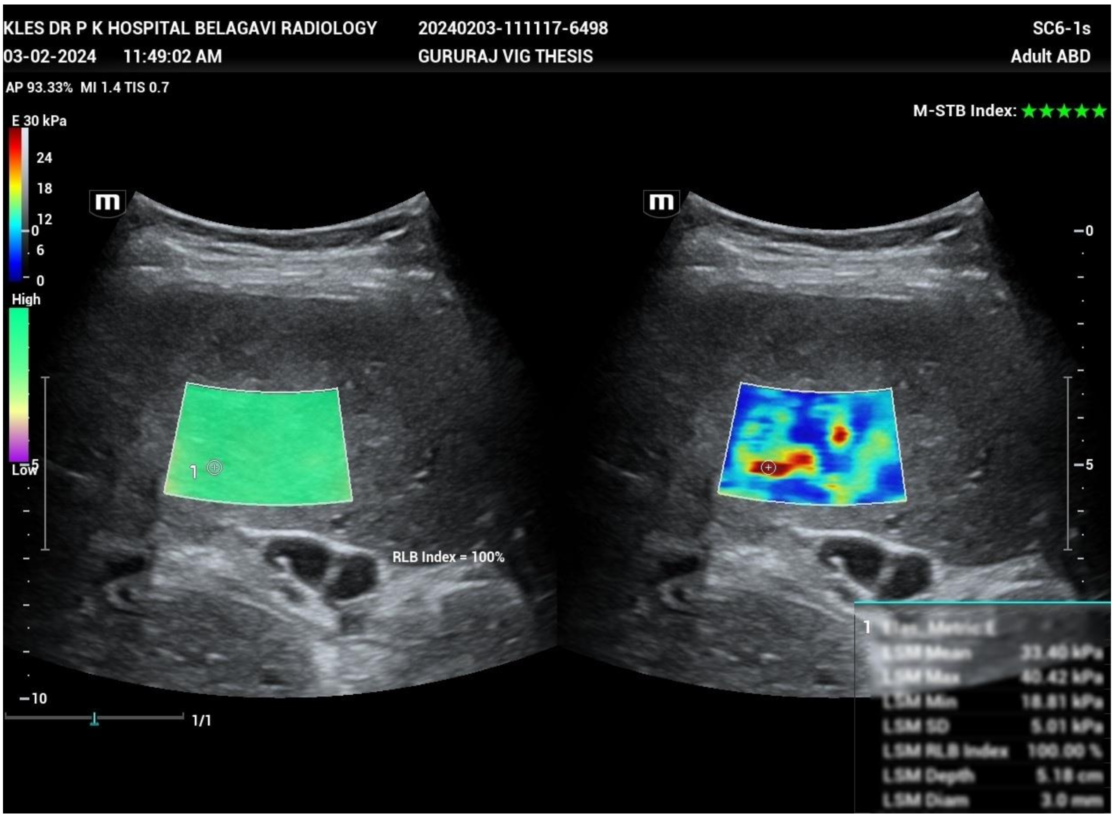


**Image 2: Showing a case of hepatocellular carcinoma with the mean stiffness values of 38.8 kPa and the hardest part of the lesion shows mean stiffness values of 40.2 kPa**



1 Elas. Metric E

| | |
|---|---|
| LSM Mean | 33.40 kPa |
| LSM Max | 40.42 kPa |
| LSM Min | 18.81 kPa |
| LSM SD | 5.01 kPa |
| LSM RLB Index | 100.00 % |
| LSM Depth | 5.18 cm |
| LSM Diam | 3.0 mm |

**Image 3: Showing a case of mass forming cholangiocarcinoma with the mean stiffness values of 55.4 kPa and the hardest part of the lesion shows mean stiffness values of 74.2 kPa**

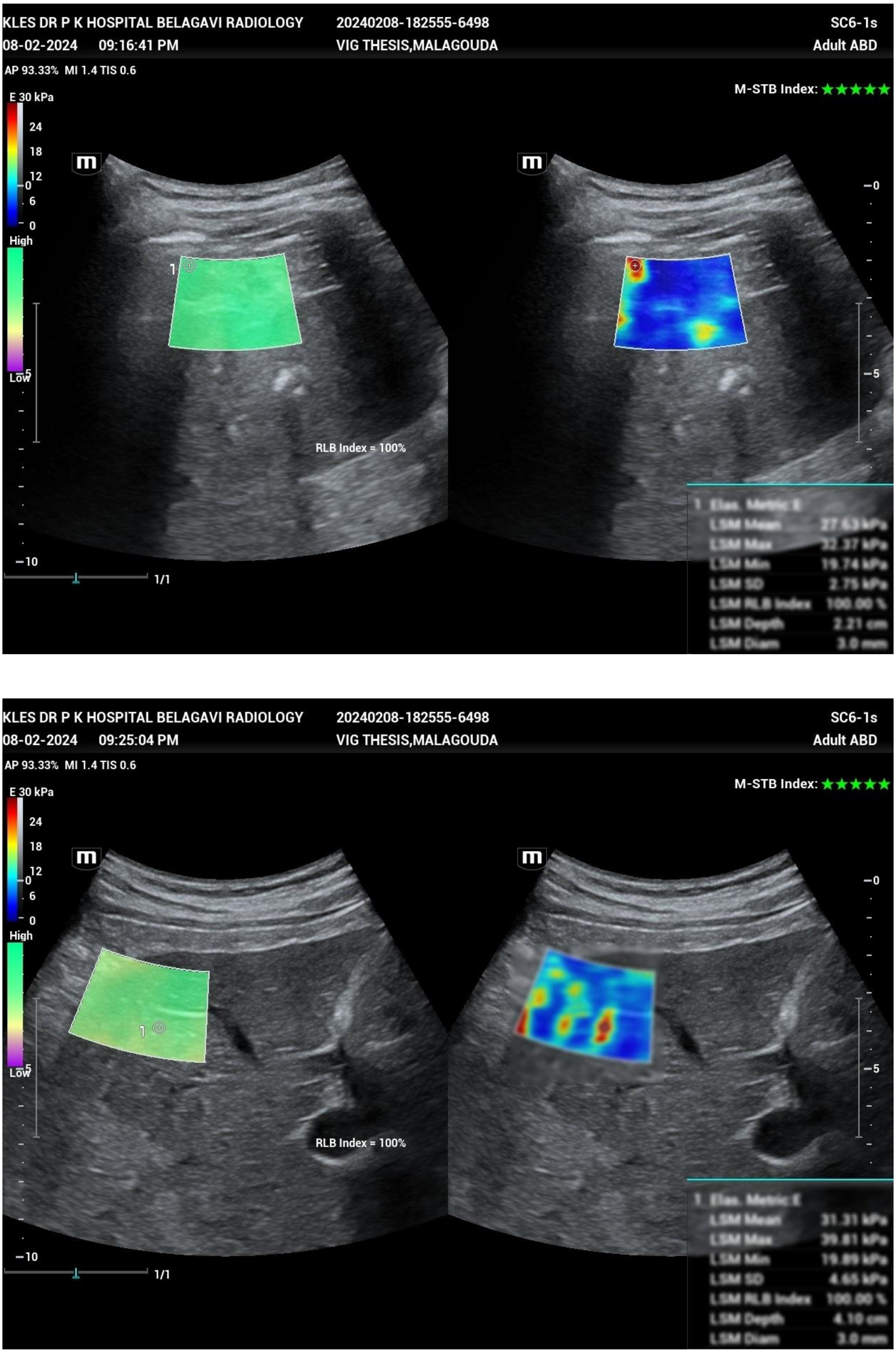


**Image 4: Showing a case of hepatic metastases (primary carcinoma of right breast ) with the mean stiffness values of 42.3.2 kPa and the hardest part of the lesion shows mean stiffness values of 49.7kPa**

# ANNEXURE IV: MASTER CHART

| | | | LIVER CHANGES | | | GREY SCALE FINDINGS | | | COLOUR DOPPLER FEATURES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | MARGINS | | | | ECHOGENICITY | | | OTHER LAB INVESTIGATIONS | | | ELASTOGRAPHY VALUES | | | |
| SL.NO | PATIENT ID | AGE | SEX | NORMAL LIVER | FATTY LIVER | CHRONIC LIVER DISEASE | WELL DEFINED | ILL DEFINED | INTERNAL VASCULARITY PRESENT | INTERNAL VASCULARITY ABSENT | | DIMENSIONS OF THE LESION | | NORMAL | ABNORMAL | CONFIRMATORY CT | WITHIN THE LESION (kPa) | HARDEST PART OF LESION (kPa) | BENIGN | MALIGNANT |
| 1 | 10125339 | 75 | M | | | CHRONIC LIVER DISEASE | | ILL DEFINED | HETEROECHOIC | PRESENT | | 3.4 X 2.5 CMS | | | INCREASED ALT , AST & AFP | YES | 38.8 | 40.3 | | HEPATOCELLULAR CARCINOMA |
| 2 | 12467 | 55 | M | | GRADE I FATTY LIVER | | | ILL DEFINED | HYPOECHOIC | PRESENT | | 2.3 X 2.0 CMS | | NORMAL ALT AND AST | | YES | 55.4 | 74.2 | | CHOLANGIOCARCINOMA |
| 3 | 7896789 | 60 | M | | GRADE II FATTY LIVER | | | ILL DEFINED | HETEROECHOIC | PRESENT | | 3.4 X 2.5 CMS | | | INCREASED ALT AND AST | YES | 37.2 | 47.18 | | HEPATOCELLULAR CARCINOMA |
| 4 | 53745 | 59 | M | | | CHRONIC LIVER DISEASE | | ILL DEFINED | HYPOECHOIC | PRESENT | | 6.7 X 6.6 CMS | | NORMAL ALT AND AST | | YES | 38.6 | 50.2 | | HEPATOCELLULAR CARCINOMA |
| 5 | 1234856 | 30 | M | NORMAL | | | | ILL DEFINED | HETEROECHOIC | PRESENT | | 4.9 X 4.0 CMS | | NORMAL ALT AND AST | | YES | 32.4 | 44.3 | | HEPATIC METASTSES |
| 6 | 10127374 | 55 | F | NORMAL | | | WELL DEFINED | | HYPERECHOIC | | ABSENT | 3.0 X 2.0 CMS | | NORMAL ALT AND AST | | NO | 12.4 | 13.54 | HEMANGIOMA | |
| 7 | 10127435 | 59 | M | NORMAL | | | | ILL DEFINED | HETEROECHOIC | PRESENT | | 3.1 X 2.2 CMS | | | ELEVATED GGT | NO | 54.3 | 76.6 | | CHOLANGIOCARCINOMA |
| 8 | 10347372 | 55 | M | NORMAL | | | | ILL DEFINED | HETEROECHOIC | PRESENT | | 1.8 X 1.8 CMS | | | INCREASED ALT , AST & AFP | YES | 50 | 81.1 | | CHOLANGIOCARCINOMA |
| 9 | 10223376 | | M | | | CHRONIC LIVER DISEASE | | ILL DEFINED | HYPOECHOIC | PRESENT | | 6.3 X 5.3 CMS | | NORMAL ALT AND AST | | NO | 40 | 42.4 | | HEPATOCELLULAR CARCINOMA |
| 10 | 10075089 | 76 | M | | | CHRONIC LIVER DISEASE | | ILL DEFINED | HYPOECHOIC | PRESENT | | 4.4 X 3.2 CMS | | | ELEVATED AST AND ALT VALUES | YES | 39 | 42.5 | | HEPATOCELLULAR CARCINOMA |
| 11 | 10025238 | 56 | F | | GRADE II FATTY LIVER | | WELL DEFINED | | HETEROECHOIC | PRESENT | | 3.0 X 2.0 CMS | | NORMAL LFT | | NO | 37.2 | 44.8 | | HEPATIC METASTASES IN CASE OF CARCINOMA BREAST |
| 12 | 4152-24 | 52 | M | | GRADE I FATTY LIVER | | WELL DEFINED | | HYPOECHOIC | | ABSENT | 5.0 X4.0 MM | | NORMAL LFT | | YES | 8.9 | 10.2 | | FOCAL AREA OF FAT SPARING -BENIGN |
| 13 | 4691-25 | 60 | F | NORMAL | | | WELL DEFINED | | HYPERECHOIC | | ABSENT | 3.0 X 2.0 CMS | | NORMAL LFT | | YES | 5.6 | 7.1 | HEMANGIOMA | |
| 14 | 107940 | 66 | M | NORMAL | | | WELL DEFINED | | HYPERECHOIC | PRESENT | | 4.1 X 3.2 CMS | | | ELEVATED GAMMA GLUTAMYL TRANSPEPTIDASE | NO | 37.8 | 47.8 | | HEPATOCELLULAR CARCINOMA |
| 15 | 6419557 | 74 | M | | | CHRONIC LIVER DISEASE | WELL DEFINED | | HYPOECHOIC | PRESENT | | 1.5 X 1.4 CMS | | | ELEVATED AST , ALT & GGT | YES | 29.6 | 35.2 | | HEPATOCELLULAR CARCINOMA |
| 16 | 104817 | 55 | M | | | CHRONIC LIVER DISEASE | WELL DEFINED | | HYPOECHOIC | PRESENT | | 5.9 X 5.0 CMS | | NORMAL LFT | | NO | 35.7 | 43.2 | | MULTICENTRIC HEPATOCELLULAR CARCINOMA |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 70069 | 89 | F | | | CHRONIC LIVER DISEASE | WELL DEFINED | | HETEROECHOIC | PRESENT | | 5.2 X 4.8 CMS | | | ELEVATED AST AND ALT VALUES | YES | 34.2 | 49.3 | | HEPATOCELLULAR CARCINOMA / METASTASES |
| 18 | 93186 | 70 | M | NORMAL | | | | ILL DEFINED | HETEROECHOIC | PRESENT | | 9.9 X 9.8 CMS | | | ELEVATED AST , ALT & GGT | NO | 35.7 | 43.3 | | HEPATOCELLULAR CARCINOMA |
| 19 | 101320 | 56 | M | | | CHRONIC LIVER DISEASE | WELL DEFINED | | HYPERECHOIC | | ABSENT | 5.2 X 5.2 CMS | | NORMAL ALT AND AST | | YES | ,8.4 | 9.9 | HEMANGIOMA | |
| 20 | 7638-24 | 32 | M | NORMAL | | | | ILL DEFINED | HYPOECHOIC | PRESENT | | 5.2 X 5.2 CMS | | | ELEVATED AST & ALT | YES | 53.4 | 82 | | HILAR CHOLANGIOCARCINOMA |
| 21 | 7634-24 | 76 | M | | GRADE I FATTY LIVER | | | ILL DEFINED | HYPOECHOIC | PRESENT | | 5.0 X 3.0 CMS | | NORMAL LFT | | NO | 38.2 | 42.1 | | HEPATIC METASTASES |
| 22 | 5694-24 | 74 | M | | | CHRONIC LIVER DISEASE | | ILL DEFINED | HYPOECHOIC | PRESENT | | 5.0 X 4.0 CMS | , | | ELEVATED AST , ALT & GGT | YES | 37.7 | 48.9 | | HEPATOCELLULAR CARCINOMA |
| 23 | 3940-24 | 57 | M | NORMAL | | | | ILL DEFINED | HYPOECHOIC | PRESENT | | 3.4 X 3.2 CMS | | NORMAL LFT | | NO | 43.4 | 45.6 | | HEPATIC METASTASES |
| 24 | 104465 | 68 | M | | | CHRONIC LIVER DISEASE | | ILL DEFINED | HYPOECHOIC | PRESENT | | 3.0 X 3.0 CMS | | | ELEVATED AST , ALT & GGT | YES | 39.4 | 43.4 | | HEPATOCELLULAR CARCINOMA |
| 25 | 108623 | 72 | M | NORMAL | | | WELL DEFINED | | HYPOECHOIC | | ABSENT | 3.0 X 2.5 CMS | | NORMAL ALT AND AST | | NO | 1.4 | 3.4 | HEPATIC ADENOMA | |
| 26 | 98072 | 47 | M | NORMAL | | | | ILL DEFINED | HYPOECHOIC | PRESENT | | 6.7 X 6.6 CMS | | NORMAL ALT & AST | | YES | 42.3 | 49.7 | | HEPATIC METASTASES |
| 27 | 104342 | 85 | F | | GRADE I FATTY LIVER | | WELL DEFINED | | HYPOECHOIC | | ABSENT | 5.9 X 5.5 CMS | | NORMAL ALT AND AST | | YES | 3.4 | 6.7 | HEPATIC ADENOMA | |
| 28 | 90205 | 63 | F | NORMAL | | | WELL DEFINED | | HYPERECHOIC | | ABSENT | 7.8 X 7.8 CMS | | NORMAL ALT AND AST | | NO | 5.6 | 7.6 | HEMANGIOMA | HEMANGIOMA - BENIGN |
| 29 | 81207 | 45 | M | | | CHRONIC LIVER DISEASE | WELL DEFINED | | ISOECHOIC | | ABSENT | 4.2 X 3.2 CMS | | NORMAL ALT AND AST | | YES | 8.9 | 9.2 | FNH | |
| 30 | 63855 | 69 | M | NORMAL | | | | ILL DEFINED | HETEROECHOIC | PRESENT | | 4.0 X 3.5 CMS | | | ELEVATED AST , ALT & GGT | NO | 38.9 | 48.6 | | HEPATOCELLULAR CARCINOMA |
| 31 | 755025 | 34 | F | NORMAL | | | WELL DEFINED | | HYPERECHOIC | | ABSENT | 2.4 X 2.8 CMS | | NORMAL ALT AND AST | | YES | 8.9 | 9.7 | HEMANGIOMA | |
| 32 | 1056743 | 56 | F | | | CHRONIC LIVER DISEASE | | ILL DEFINED | HETEROECHOIC | PRESENT | | 5.6 X 4.3 CMS | | | ELEVATED GGT | NO | 44.5 | 44.5 | | HEPATIC METASTASIS |