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Original Research Article

The Role of Shear Wave Elastography to Evaluate Liver Stiffness in Patients with Fatty Liver Diagnosed on B Mode Ultrasonography in Patient with No History of Alcohol Consumption

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Abstract

Background: Non-alcoholic fatty liver disease (NAFLD) is an increasingly prevalent condition associated with hepatic steatosis in the absence of significant alcohol consumption. While B-mode ultrasound is commonly used for diagnosis, it cannot quantify liver fibrosis—a crucial determinant of prognosis. Shear wave elastography (SWE) offers a non-invasive method to assess liver stiffness and potentially detect early fibrosis.

Materials and Methods: The study was undertaken from March 2025 to august 2025 after obtaining Institutional Review Board (IRB) approval in patients referred to the department of Radio diagnosis, Narendra Modi Medical College & L.G hospital, Ahmedabad. The study population consisted first 100 patients with no history of alcohol consumption were diagnosed having fatty liver on B mode ultrasound and undergone shear wave elastography over 6 months. Liver stiffness values were recorded using a Mindray Resona I9 ultrasound machine.

Results: In this study of 100 patients, 60 patients were male while 40 patients were female. The most common age group affected was 40-49 years.Fatty liver grading on B mode ultrasound revealed 50 patients (50.0%)in Grade I, 35 patients (35.0%) in Grade II, and 15 patients (15.0%) in GradeIII. SWE measurements showed distinct ranges: Grade I (5.04 ± 0.65 kPa), Grade II (6.99 ± 0.80 kPa), and Grade III (9.74 ± 0.77 kPa). A positive correlation was observed between fatty liver grading on B mode ultrasound and SWE values ($r = 0.912$, $p < 0.001$).

Conclusion: Shear wave elastography demonstrates excellent correlation with B-mode fatty liver grading in NAFLD patients. The mean SWE values observed in our study (Grade I: 5.04 kPa, Grade II: 6.99 kPa, Grade III: 9.74 kPa) demonstrate a clear stepwise progression that mirrors the expected increase in liver stiffness with advancing fatty liver disease, enabling noninvasive fibrosis risk stratificationwithout liver biopsy.

Keywords: Shear wave elastography, Nonalcoholic fatty liver diseases, liver stiffness, B mode ultrasonography, liver fibrosis, noninvasive imaging.

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Introduction

Non-alcoholic fatty liver disease (NAFLD) has emerged as the most prevalent chronic liver disease worldwide, affecting approximately 25–30% of the global adult population. It is histologically defined as the abnormal accumulation of fat (>5%) in the hepatocytes in the absence of secondary causes of fatty liver disease, such as significant alcohol consumption or viral infection. The severity of liver steatosis is graded as S0 when histological involvement is minimal (<5% of hepatocytes), S1 or mild (5–33% of hepatocytes), S2 or moderate (34–66%) and, finally, S3 or severe when >66% of liver cells show the intrahepatic accumulation of lipids. Despite the rising interest and gains in our understanding of NAFLD/NASH pathogenesis over the last two decades, there has been some dissatisfaction with the terminology "non-alcoholic" because it overstresses the role of alcohol and plays down the role of metabolic risk factors in the development of the disease. Therefore, a name change from NAFLD to metabolic-associated fatty liver disease (MAFLD) has been proposed [9]. B-mode ultrasonography is the most commonly used imaging modality for the initial detection of fatty liver due to its widespread availability, non-invasiveness, and affordability. While B-mode ultrasound is effective in identifying hepatic steatosis and grading its severity based on echogenicity, it cannot reliably assess liver fibrosis, which is a key limitation.

The progression from simple steatosis to fibrosis is the most important determinant of long-term liver-related morbidity and mortality. Therefore, early detection of fibrosis is critical for risk stratification, prognosis, and therapeutic decision-making in NAFLD patients. Liver biopsy remains the gold standard for the assessment of fibrosis; however, it is invasive, costly, associated with patient discomfort, and subject to sampling errors and interobserver variability. Shear wave elastography (SWE) has been introduced as a non-invasive, quantitative technique to assess liver stiffness, which correlates strongly with histological fibrosis. SWE utilizes acoustic radiation force impulse (ARFI) technology to generate and measure the propagation velocity of shear waves in liver tissue, providing liver stiffness measurements in kilopascals (kPa). The meta-analysis of histological data in viral hepatitis (METAVIR) scoring system by Bedossa et al. [10] is the most commonly used tool to evaluate the severity of fibrosis. It integrates five fibrosis stages: F0 (no fibrosis), F1 (mild fibrosis, portal fibrosis without septa), F2 (significant fibrosis, portal fibrosis with few septa), F3 (severe fibrosis, numerous septa without cirrhosis), and F4 (cirrhosis). Despite the growing body of evidence supporting elastography in chronic liver disease, limited data exist regarding the correlation between B-mode fatty liver grading and SWE measurements in NAFLD patients. Understanding this relationship could enhance diagnostic accuracy and provide objective criteria for disease severity assessment. Therefore, this study aimed to evaluate the correlation between B-mode ultrasonographic fatty liver grading and liver stiffness measured by shear wave elastography in patients with NAFLD.

Materials and Methods

Study design, duration and settings: This was a hospital-based prospective observational study conducted in the Department of Radiodiagnosis, Narendra Modi Medical College and L.G. Hospital, Maninagar, Ahmedabad, Gujarat, India between March 2025 and august 2025 for a duration of 6 months.

Equipment Used: Mindray Resona I9 ultrasound machine for B mode ultrasonography and elastography

Inclusion criteria

- Patients of any age / gender who were diagnosed having fatty liver disease on B mode ultrasound and undergone elastography study of liver.
- Patients with no history of alcohol consumption.

Exclusion criteria

- All patients who don't give consent / assent of parent or guardian for participation in the study.
- Patients with ultrasonographic findings consistent with cirrhosis like:

Irregular, nodular liver surface contour, Heterogeneous liver parenchyma with coarse echotexture, Caudate lobe hypertrophy with relative atrophy of other segments.

- Portal hypertension manifestations: ascites, splenomegaly (>12cm), dilated portal vein (>13mm), presence of portosystemic collaterals

Advantage

- Available more readily, cost effective and less time consuming.
- Understanding the relationship between fatty liver severity on ultrasound and liver stiffness on shear wave elastography can help identify high risk patients without the need for liver biopsy.

Limitation

- Intermediate results of elastography.
- Inter and intraoperator dependent.

Source of data: Patients who undergo B mode ultrasound and diagnosed having fatty liver disease in nonalcoholic patients (based on history) & elastography study of liver in the department of radio- diagnosis at L. G. hospital, Narendra Modi Medical College, Maninagar, Ahmedabad for duration of 6 months from the IRB approval after obtaining an informed written consent.

Study type: Prospective observational single centered study.

Sample Size & Study Period: Minimum 100 cases from March 2025 to August 2025 after obtaining IRB approval.

Results

Table 1: Distribution of Patients According to Gender (N=100)

Gender	No. of Patients	Percentage
Male	60	60 %
Female	40	40 %
Total	100	100 %

Out of 100 patients included in the study, 60 were males (60%) & 40 were females (40%).

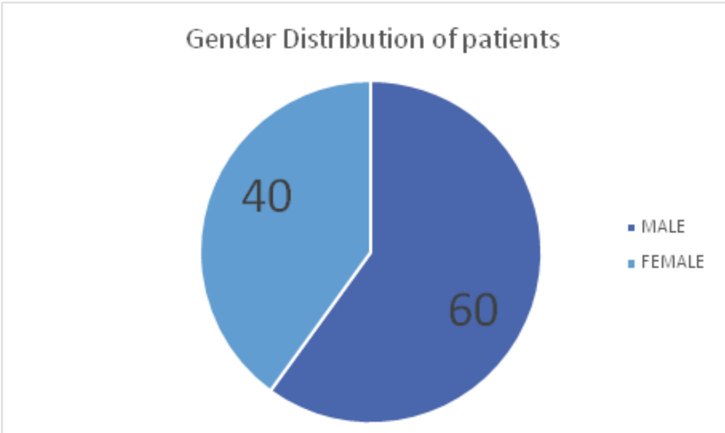

Figure 1: Distribution of Patients According to Gender (n=100)

Table 2: Distribution of Patients According to Age(N=100)

Age	No. of Patients	Percentage
<18	4	4.0%
18-29	8	8.0%
30-39	22	22.0%
40-49	30	30.0%
50-59	26	26.0%
60-69	5	5.0%
>70	5	5.0%
Total	100	100%

In this study out of 100 patients, maximum number of patients were from the age group of 40 to 49 years age (30.0%) followed by age group of 50 to 59 year of age (26.0%). Least number of patients were in age group of 60 to 69 years of age (5.0 %) and in age group greater than 70 years (5.0 %) followed by age group less than 18 years (4.0%). Indicating that non-alcoholic fatty liver diseases was most common in the middle-aged adult population.

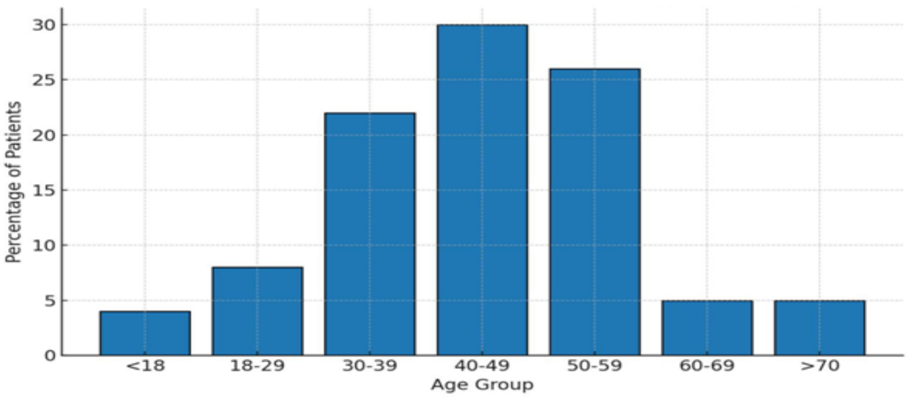

Figure 2: Distribution of Patients According to Age (n=100)

Table 3: Fatty Liver Grade Distribution on B Mode Ultrasound

Grade	No. of patients	Percentage
Grade 1	50	50.0%
Grade 2	35	35.0%
Grade 3	15	15.0%
Total	100	100%

In this study out of 100 patients, maximum cases (50%) were fatty liver grade 1, followed by 35% were of grade 2 and rest cases were of fatty liver grade 3.

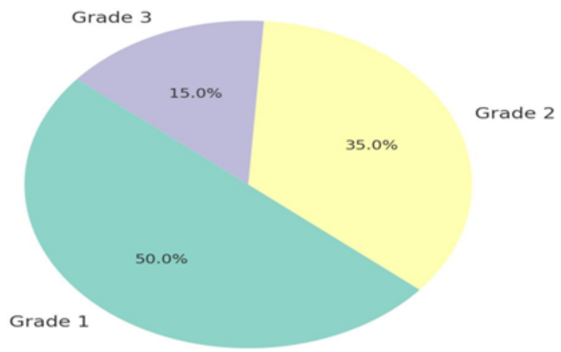

Figure 3: Distribution of Fatty Liver Grades ONB Mode Ultrasound

Table 4: Liver Stiffness Measurements in Different Fatty Liver Grade (Shear Wave Elastography)

Fatty Liver Grade	Patient count	Mean Stiffness (kPa)	Standard Deviation
Grade 1	50	5.04	± 0.65
Grade 2	35	6.99	± 0.80
Grade 3	15	9.74	± 0.77
Total	100		

In this study of 100 patients, liver stiffness measurements were obtained using shear wave elastography (SWE). The mean liver stiffness in patients with Grade 1 fatty liver was 5.04 kPa (±0.65), whereas in Grade 2 it was 6.99 kPa (±0.80), and the highest stiffness was noted in Grade 3 fatty liver, with a mean value of 9.74 kPa (±0.77).

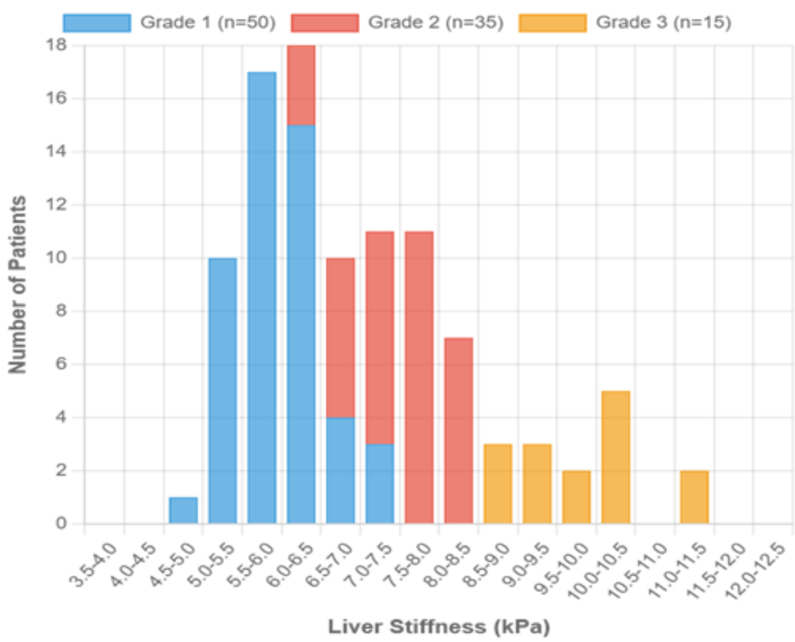

Figure 4: Liver Stiffness Measurements in Different Fatty Liver Grade (Shear Wave Elastography)

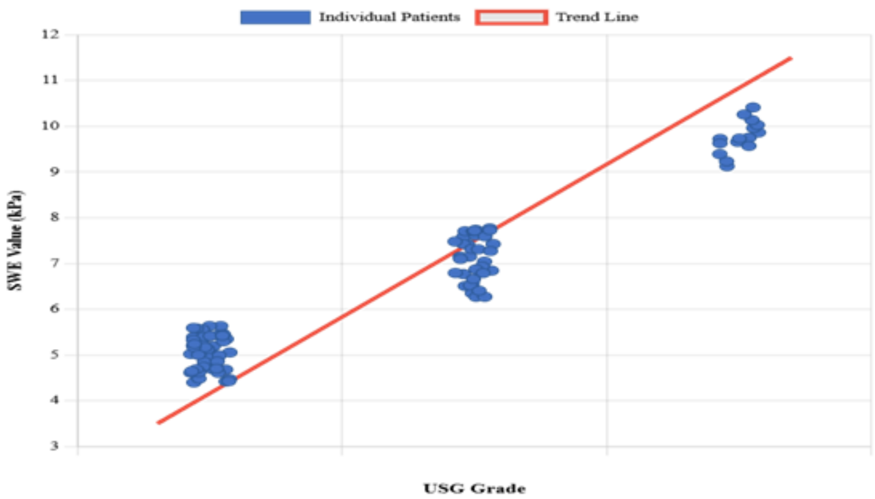

Figure 5: Scatter Plot Demonstrating Correlation Between Fatty Livergrades on B Mode Ultrasound and SWE Values

Correlation Analysis:
Pearson correlation coefficient: r = 0.912
95% Confidence Interval: 0.87-0.94
p-value: < 0.001

Figure 5 Scatter plot demonstrating positive correlation between fatty liver grades on B mode ultrasound and SWE values (r = 0.912, p < 0.001). Each point represents an individual patient measurement. The strong correlation indicates that SWE can reliably quantify liver stiffness progression corresponding to increasing fatty liver severity on B-mode ultrasound.

Discussion

This prospective study demonstrates an excellent correlation (r = 0.912, p < 0.001) between B-mode ultrasonographic fatty liver grading and liver stiffness measured by shear wave elastography in patients with NAFLD. The study included 100 patients with maximum number of patients in the age group of [40-49] years, with male predominance (60%) over female (40%). All patients underwent both B-mode ultrasound fatty liver grading and SWE assessment using the Mindray Resona I9 ultrasound system.

B-mode Ultrasound Fatty Liver Grading and SWE Correlation

Ultrasonography: USG is a safe, radiation-free, easily available, cost-effective way of determining fatty infiltration of liver. The examination can be performed using a 2-5 MHz convex transducer. The normal liver parenchyma has a homogeneous echotexture with echogenicity equal to or slightly greater than that of the renal cortex and spleen.

The liver shows echogenicity higher than the renal cortex and spleen due to fatty infiltration. Various (0-3) grades of steatosis have been proposed based on visual analysis of the intensity of the echogenicity, provided that the gain setting is optimum [Figure 1]. when there is a slight and diffuse increase of liver echogenicity with normal visualization of the portal vein wall and diaphragm, it is grade I; moderate increase of liver echogenicity with slightly impaired appearance of the portal vein wall and the diaphragm, it is grade II and in case of marked increase of liver echogenicity with poor or no visualization of portal vein wall and diaphragm, it is grade III fatty infiltration. These are however subject to inter-observer variation.

Pathologically reduced renal cortical echogenicity can cause apparent hepatic hyperechogenicity on ultrasound comparison, potentially resulting in false-positive diagnosis of fatty liver disease when hepatic echogenicity is objectively normal. In such cases, comparison with splenic echogenicity provides a more reliable assessment, as the spleen remains unaffected by renal pathology.

The distinct SWE ranges observed for each fatty liver grade on B mode ultrasound demonstrate clear stepwise progression that mirrors the expected increase in liver stiffness with advancing fatty liver disease (Figure 1). In our study, Grade I fatty liver showed mean SWE values of 5.04 ± 0.65 kPa, Grade II showed 6.99 ± 0.80 kPa, and Grade III showed 9.74 ± 0.77 kPa. The absence of overlapping 95% confidence intervals between groups confirms statistical significance and suggests excellent discriminatory capability.

The METAVIR scoring system represents the gold standard for histological fibrosis staging, categorizing liver fibrosis from F0 (no fibrosis) to F4 (cirrhosis). Establishing correlations between SWE measurements and METAVIR-equivalent staging could provide clinicians with a non-invasive alternative to liver biopsy for fibrosis assessment.[10]

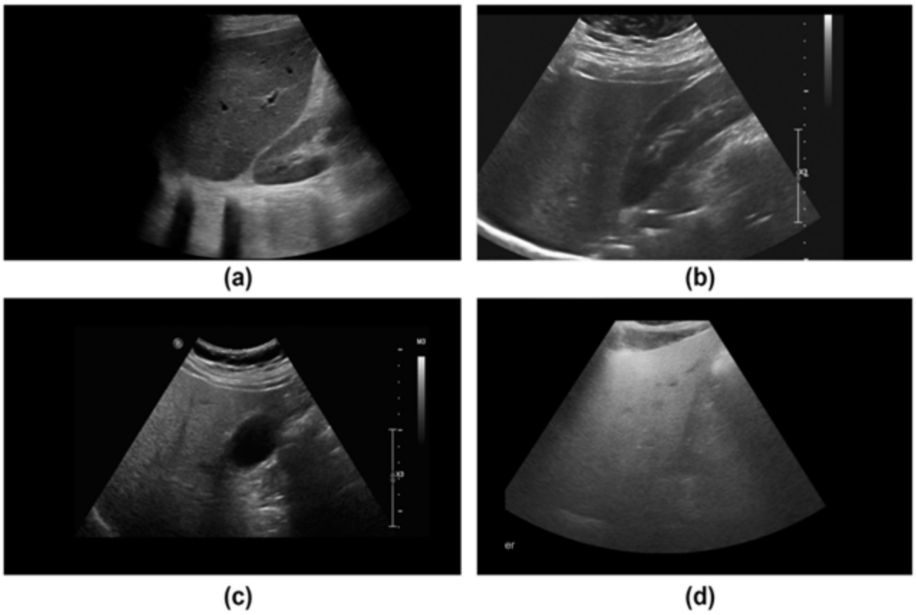

Figure 6: Ultrasound image shows (a) Normal liver echogenicity (b) Grade 1 fatty liver with increased liver echogenicity (c) Grade 2 fatty liver with the echogenic liver obscuring the echogenic walls of the portal venous branches (d) Grade 3 fatty liver in which the diaphragmatic outline is obscured

B-mode ultrasound images showing different grades of fatty liver

Elastography: Different ultrasound based non-invasive elastography techniques have been developed to estimate changes in tissue stiffness and thus offer alternatives to invasive methods like biopsy. Among various elastographic methods, Shear Wave Elastography (SWE) is of recent great interest and it includes three different techniques, as showed in Table 1. Even if transient elastography (TE) - where tissue stiffness is quantified by measuring the speed of a propagating shear wave, and estimated along an ultrasonic A-line, in a fixed region, which is neither user adjustable nor image guided - has shown significant positive correlation with the stage of liver fibrosis and has entered clinical use in many European countries , real-time shear wave elastography , on the other hand, is a new technique where the shear wave speed is again used to quantify the elasticity via a given equation.

The Point SWE uses an acoustic radiation force impulse to induce shear waves in liver tissue. The performance of pSWE is assisted by its incorporation into standard B-mode US acquisition. This technique permits an operator to visualize the liver tissue and select a region without blood vessels, rib shadows, or bile ducts.

The pSWE produces a single point of energy within the liver and targets a region of interest (ROI) of 5 × 10 mm using B-mode imaging. The measured shear wave speed is expressed in m/s and converted to Young's modulus in kPa for the estimation of tissue stiffness. Ten measurements should be obtained from 10 independent images, in the same location.

Table 5: Shear Wave Elastography methods

1. Transient Elastography (TE)
2. Point SWE:
• Acoustic Radiation Force Impulse Elastography (ARFI);
• ElastPQ technique;
3. Real Time SWE:
• Two-dimensional SWE (2D-SWE);
• Three-dimensional SWE (3D-SWE);

Principle of 2D-Shear Wave Elastography: The principle of 2D-SWE is a combination of a radiation force induced into the tissues by focused ultrasonic beams and a very high frame rate ultrasound imaging sequence, able to capture the propagation of the resulting shear waves in real time. To capture them in sufficient detail, frame rates of thousands of images per second are needed, so that the ultra-fast imaging mode could acquire raw radio-frequency data.

As Frulio et al. describe the phenomenon, the propagation speed of the shear wave is estimated from the movie thus created and a two-dimensional color map is displayed. Elasticity is displayed using a color-coded image superimposed on a B-mode image: in red – stiffer tissues and in blue – softer tissues. However, the color coding is machine-dependent and may vary according to manufacture-specific algorithms and settings. Each color codes either the shear wave speed in meters per second (m/s), or the elasticity of the medium in kilopascals (kPa), accompanied, in real time imaging mode, by an anatomic reference gray scale (or B-mode) image as demonstrated in our representative cases (Figures 2, 3, and 4). This real-time imaging mode enables quantitative measurements by positioning one or more regions of interest (ROI—also known as Q-Box). The measurements should be performed from the right lobe of liver through intercostal spaces about 1.5–2 cm below the liver capsule in supine position after 3-4 hours of fasting, avoiding ribs, vessels and intrahepatic biliary radicles. The ROI can be adjusted to variable sizes (3–700 mm^2). Consequently, a quantitative estimation of liver stiffness is performed, the mean liver stiffness value in the region of interest, as well as the standard deviation of the measured elasticity being displayed on the screen as shown in Figure 2, supersonic shear imaging measurement is performed inside the circle, which should be positioned in an area of homogeneous color. The softer tissue (blue area) will calculate the mean, minimum, maximum and standard deviation of the measurement, as well as the diameter of the circle. Even if ten stiffness values obtained from 10 independent images in the same location are generally required for liver ultrasound elastography, when a quality assessment parameter (confidence map) is used, five measurements may be appropriate.

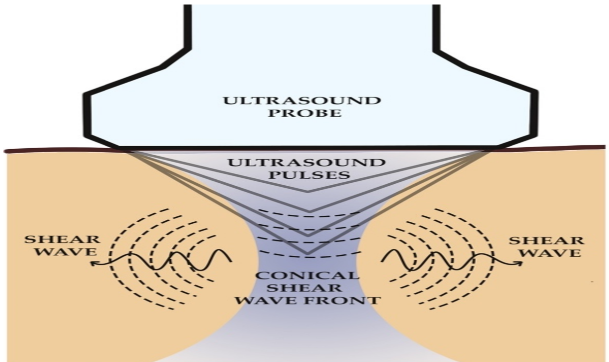

Figure 7:

SWE Measurements and Technical Considerations: The correlation coefficient of 0.912 observed in our study is notably higher than most previously published elastography studies. Sporea et al. reported correlations ranging from 0.65-0.78 when comparing 2D-SWE with histological fibrosis staging, while other studies using transient elastography have shown correlations between 0.6-0.8. Our superior correlation may be attributed to several factors: the use of advanced 2D-SWE technology (Mindray Resona I9), careful patient selection excluding advanced cirrhosis, and standardized measurement protocols. The narrow standard deviations within each grade (0.65-0.80 kPa) indicate good measurement precision and reproducibility. All SWE measurements were obtained from the right lobe of liver through intercostal spaces following standardized protocols to minimize technical variables.

2D-SWE Utility, Reliability and Reproducibility: The main limitation and disadvantage of 2D-SWE would be its novelty and, therefore, the lack of uniformous testing and results especially in what NAFLD and liver steatosis are concerned. On the other hand, several advantages are reported in recent studies. Among these, it is to be acknowledged that 2D-SWE is an easy, painless, rapid technique showing good intraoperator reproducibility with an intra-class correlation coefficient of 0.95 - when measurements are taken the same day -and 0.84 - when taken in different days, yet by the same operator; furthermore, 2D-SWE is characterized by good inter-operator reproducibility and provides an immediate result within any ultrasound check, as 2D-SWE is incorporated onto a conventional ultrasound diagnostic imaging device, which allows the combination, in one exam, of quantitative elastography assessment of the liver fibrosis and after its morphological ultrasound examination [6]

Comparison with Existing Literature: Our findings demonstrate superior diagnostic performance compared to existing studies. In a study by [Ferraioli et al.]__[7], SWE showed correlation coefficients of 0.76 for liver fibrosis assessment, while our study achieved r = 0.912. This improvement may be attributed to our focus on the correlation between B-mode ultrasound fatty liver grading and SWE measurements, rather than direct histological correlation, which eliminates sampling bias inherent in liver biopsy.

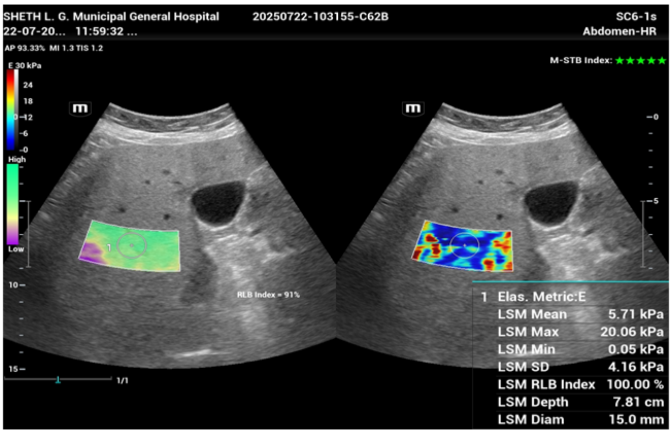

Figure 8: Representative SWE elastography image showing liver stiffness measurement. The elastography box (right panel) demonstrates color-coded stiffness map with quantitative measurements: LSM Mean 5.71 kPa, corresponding to Grade I fatty liver on B mode ultrasound with F0-F1-equivalent fibrosis staging

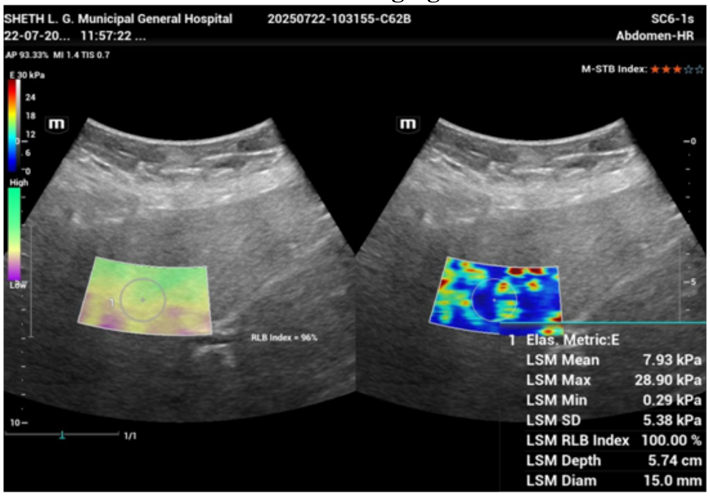

Figure 9: Representative SWE elastography image showing liver stiffness measurement. The elastography box (right panel) demonstrates color-coded stiffness map with quantitative measurements: LSM Mean 7.93 kPa, corresponding to Grade II fatty liver on B mode ultrasond with F2-equivalent fibrosis staging

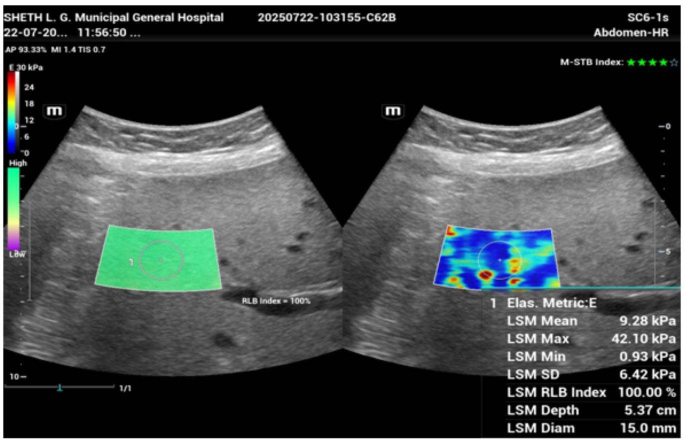

Figure 10: Representative SWE elastography image showing liver stiffness measurement. The elastography box (right panel) demonstrates color-coded stiffness map with quantitative measurements: LSM Mean 9.28 kPa, corresponding to Grade III fatty liver on B mode ultrasound with F3-equivalent fibrosis staging

Our study demonstrates the reliability and feasibility of SWE using the Mindray Resona I9 system in routine clinical practice, as shown in our representative elastography images (Figures 2-4).

Clinical Implications and Applications: The strong correlation between B-mode ultrasound fatty liver grading and SWE measurements has several important clinical implications for NAFLD management.

Objective Disease Assessment: Traditional B-mode fatty liver grading is inherently subjective and operator-dependent. Our findings suggest that SWE can provide objective, numerical values that strongly correlate with visual assessment, potentially reducing inter-observer variability and improving diagnostic consistency across different operators and institutions.

Conclusion

This study demonstrates that shear wave elastography provides excellent correlation with B-mode fatty liver grading in patients with NAFLD. The exceptional correlation observed (r = 0.912) supports the integration of SWE into routine clinical practice for enhanced NAFLD assessment, potentially improving standardization and objectivity in disease evaluation. These findings contribute to the evidence base for non-invasive liver fibrosis assessment and support the use of elastography as a reliable adjunct to conventional B-mode ultrasonography in NAFLD management.

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