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Article

Role of Shear Wave Elastography in Staging Liver Fibrosis in Diabetic and Cardiac Patients

Arifa Mobeen[1], Numeera Ayyaz[2], Mahnoor Fatima[2], Aleena Laraib[2], Aneeza Ayyaz[2], Isha Sagheer[2], Insharah Sattar[2]

1 Master of Science in Diagnostic Ultrasound, University of Management and Technology, Lahore, Pakistan
2 Bachelor of Science in Medical Imaging and Ultrasound, University of Management and Technology, Lahore, Pakistan

Correspondence
arifamobeen@gmail.com

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ABSTRACT

Background: Liver fibrosis is a progressive consequence of chronic liver injury, particularly in individuals with metabolic disorders such as diabetes mellitus and cardiovascular diseases. Despite the growing prevalence of these conditions, early detection of liver fibrosis remains challenging due to the invasive nature of liver biopsy. This study addresses the need for reliable, non-invasive techniques to stage liver fibrosis in high-risk populations. **Objective:** To assess the role of Shear Wave Elastography (SWE) in staging liver fibrosis and hepatic steatosis in patients with diabetes and cardiac conditions, and to evaluate the association between comorbidities and liver stiffness and steatosis levels. **Methods:** This was a cross-sectional observational study conducted at the Liver Clinic in Muslim Town, Lahore, Pakistan, including 284 adult patients (n = 284) with a history of diabetes, cardiac disease, or both. Patients with hepatitis A, B, or C were excluded. SWE was performed using the Canon Aplio i600 system, and CAP scoring was used to assess steatosis. Ethical approval was obtained from the Institutional Review Board, and all procedures complied with the Declaration of Helsinki. Data were analyzed using SPSS version 25, applying descriptive statistics and Chi-square tests. **Results:** Among 284 patients, 28.9% exhibited advanced fibrosis (F3–F4), and 57% showed moderate-to-severe steatosis (S2–S3). The highest prevalence of fibrosis and steatosis was observed in patients with both diabetes and hypertension. A statistically significant association was found between metabolic comorbidities and elevated liver stiffness and CAP scores ($p < 0.05$), reinforcing the clinical utility of SWE in early fibrosis detection. **Conclusion:** SWE is a non-invasive, effective diagnostic modality for staging liver fibrosis in diabetic and cardiac patients. Its integration into routine screening can enhance early identification, guide timely interventions, and mitigate long-term hepatic complications in high-risk populations.

Keywords: Liver Fibrosis, Shear Wave Elastography, Diabetes Mellitus, Cardiovascular Diseases, Hepatic Steatosis, Controlled Attenuation Parameter, Non-Invasive Diagnosis

INTRODUCTION

Liver fibrosis is a progressive pathological condition characterized by excessive accumulation of extracellular matrix (ECM) proteins, predominantly collagen, as a result of chronic liver injury. Globally, chronic liver diseases represent a significant public health burden, contributing to approximately two million deaths annually (3), with cirrhosis accounting for nearly half of these fatalities (4). The liver's pivotal roles in metabolism, detoxification, digestion, and immune regulation make it particularly susceptible to systemic disorders, especially those associated with metabolic syndromes. Among these, diabetes mellitus and cardiovascular diseases have gained increasing attention for their insidious roles in promoting hepatic damage. The intricate vascular architecture of the liver, supplied by both the portal vein and hepatic artery (1), makes it vulnerable to hemodynamic and metabolic stress imposed by comorbid conditions like diabetes and hypertension. In Pakistan, this concern is further magnified due to the country's ranking among the top ten nations with the highest burden of liver diseases, especially hepatitis-related conditions that often progress to fibrosis (5).

Non-alcoholic fatty liver disease (NAFLD), driven primarily by insulin resistance and lipid dysregulation, is emerging as a dominant etiology of liver fibrosis in both developing and developed regions. In these settings, diabetes mellitus, especially Type 2, plays a central role in hepatic steatosis and subsequent fibrogenesis. Hypertension, a frequent co-

morbidity of diabetes, exacerbates endothelial dysfunction and systemic inflammation, thereby potentiating hepatic damage. The dynamic interplay of these metabolic disorders fosters fibrogenic signaling cascades that disrupt normal liver parenchyma and stimulate fibrotic remodeling. While liver biopsy remains the gold standard for fibrosis assessment, its invasiveness and sampling limitations have spurred the development of non-invasive alternatives such as Transient Elastography (TE) and Shear Wave Elastography (SWE). SWE, by quantifying liver stiffness through the velocity of shear waves, offers a real-time, reproducible, and patient-friendly diagnostic option (7). SWE's utility extends beyond mere stiffness evaluation, providing detailed stiffness maps that inform both disease staging and therapeutic monitoring.

Despite its clinical promise, there exists a knowledge gap regarding the precise relationship between metabolic diseases—especially the combined effect of diabetes and cardiac conditions—and liver fibrosis staging using SWE. Prior studies have identified that diabetic individuals tend to exhibit higher SWE and CAP scores, indicating a correlation between metabolic dysfunction and hepatic steatosis or fibrosis (8). However, limited research has directly explored the combined influence of diabetes, hypertension, and cardiac conditions on liver stiffness and steatosis profiles. Furthermore, while cardiac dysfunction has been linked to hepatic congestion and fibrosis in advanced heart failure, its role in early-stage liver remodeling remains unclear due to limited cohort studies (Nakayama et al., 2021). Therefore, this study aims to evaluate the staging of liver fibrosis using SWE in patients with diabetes and/or cardiac diseases, investigating the extent to which these systemic conditions contribute to hepatic pathology. By leveraging a non-invasive imaging modality and analyzing its diagnostic performance across various comorbid groups, the research seeks to fill a critical void in hepatology and metabolic care integration.

This study, thus, raises a vital clinical question: To what extent do diabetes mellitus and cardiac disease, alone or in combination, influence liver stiffness and steatosis as assessed by Shear Wave Elastography in adults without underlying viral hepatitis? Addressing this question is crucial for enhancing early screening strategies and guiding timely therapeutic interventions in populations at risk for progressive liver disease.

MATERIALS AND METHODS

This cross-sectional observational study was conducted over a period of two months at the Liver Clinic in Muslim Town, Lahore, Pakistan, to evaluate the role of Shear Wave Elastography (SWE) in staging liver fibrosis in patients with diabetes and cardiac conditions. A total of 284 adult participants aged 18 years and above were enrolled. The inclusion criteria consisted of individuals with a known history of diabetes mellitus, cardiac diseases, or both, irrespective of gender. Participants with any form of viral hepatitis, including Hepatitis A, B, or C, were excluded from the study to avoid confounding etiologies of liver fibrosis. All participants provided informed consent before enrollment, and the study protocol received ethical approval from the Institutional Review Board. The study adhered to the ethical principles outlined in the Declaration of Helsinki.

Data were collected using a researcher-designed proforma capturing demographic details and clinical history, including comorbid conditions such as hypertension, diabetes, and cardiac diseases. The primary outcome was liver stiffness staging assessed through SWE, while secondary outcomes included liver steatosis levels evaluated using Controlled Attenuation Parameter (CAP) scores and grayscale ultrasound findings. SWE was performed using the Canon Aplio i600 ultrasound system equipped with a convex probe. Participants were instructed to fast for 4–6 hours prior to the examination to minimize bowel gas interference. Measurements were acquired with the patient in a supine position using a breath-hold technique during the expiratory phase. The probe was applied through the intercostal space to the right lobe of the liver. A sample box measuring 2.0 × 2.0 cm was positioned 1.0–1.5 cm below the liver capsule, avoiding major intrahepatic vessels and artifacts. Within this region, a circular region of interest (ROI) measuring 1.0–1.2 cm in diameter was selected based on the homogeneity of the propagation map. Liver stiffness measurements were taken three to five times per participant, and the average value was recorded. Grayscale imaging was also performed to classify liver echotexture as homogeneous, heterogeneous, or nodular. CAP scoring was simultaneously recorded to categorize hepatic steatosis into four grades: S0 (<0.63), S1 (0.64–0.70), S2 (0.71–0.74), and S3 (>0.75).

All collected data were entered and analyzed using SPSS version 25. Descriptive statistics were used to report frequencies and percentages for categorical variables. The Chi-square test was employed to examine associations between liver stiffness staging, CAP scoring, and comorbid conditions such as diabetes, hypertension, and cardiac disease. Cases with missing CAP scores were acknowledged, and analysis was limited to available data without imputation. Confidentiality of participant data was ensured through anonymization, and access was restricted to authorized research personnel only.

RESULTS

A total of 284 patients were included in the study, with a male predominance (63.4%, n = 180) compared to females (36.6%, n = 104). The clinical distribution of comorbidities revealed that the largest subgroup consisted of patients with both diabetes and hypertension (64.8%, n = 184), followed by diabetic-only patients (23.9%, n = 68). The smallest subgroups included cardiac-only patients (2.1%, n = 6) and those with both cardiac and diabetic conditions (1.4%, n = 4). Full breakdowns of diagnostic categories and liver assessment outcomes are presented in the tables below. Greyscale ultrasonography of the liver revealed that nearly half of the patients (49.6%) demonstrated homogeneous liver echotexture. A considerable proportion (37.7%) exhibited heterogeneous parenchyma, and 12.7% showed nodular changes, suggesting architectural distortion commonly associated with advanced fibrosis or cirrhosis.

Controlled Attenuation Parameter (CAP) scoring, available for 272 patients (95.8%), showed that the majority had moderate (S2, 35.9%) or mild (S1, 26.4%) steatosis. Severe steatosis (S3) was observed in 21.1%, and no steatosis (S0) in 12.3% of patients. Notably, patients with both diabetes and hypertension exhibited the highest representation across all steatosis categories,

particularly in the S2 group. Liver fibrosis staging assessed via Shear Wave Elastography showed that 35.2% of patients were classified as F0 (no significant fibrosis), while 18.3% exhibited F4 fibrosis consistent with cirrhosis. Mild (F1), moderate (F2), and advanced fibrosis (F3) were observed in 22.5%, 13.4%, and 10.6% of participants, respectively. The majority of patients (71.1%) fell within early-stage fibrosis (F0–F2), while 28.9% had advanced fibrosis (F3–F4).

Table 1. Diagnostic Category Distribution Among Participants

Diagnosis	Frequency (n)	Percentage (%)
Cardiac Patients	6	2.1
Diabetic Patients	68	23.9
Both Cardiac and Diabetic Patients	4	1.4
Cardiac and Hypertension Patients	5	1.8
Diabetes and Hypertension Patients	184	64.8
All Cardiac + Diabetic + Hypertension	17	6.0
Total	284	100.0

Table 2. Greyscale Ultrasonography Findings

Greyscale Pattern	Frequency (n)	Percentage (%)
Homogeneous	141	49.6
Heterogeneous	107	37.7
Nodular	36	12.7
Total	284	100.0

Table 3. CAP Score Distribution (Liver Steatosis)

CAP Score (Steatosis Grade)	Frequency (n)	Percentage (%)
S0 (<0.63)	35	12.3
S1 (0.64–0.70)	75	26.4
S2 (0.71–0.74)	102	35.9
S3 (>0.75)	60	21.1
Missing Data	12	4.2
Total	284	100.0

Table 4. Liver Fibrosis Staging by SWE

Fibrosis Stage	SWE Value (kPa)	Frequency (n)	Percentage (%)
F0	<7.0	100	35.2
F1	7.0–9.5	64	22.5
F2	9.6–12.4	38	13.4
F3	12.5–17.5	30	10.6
F4	>17.5	52	18.3
Total		284	100.0

Table 5. Liver Fibrosis Stage by Diagnosis

Diagnosis	F0	F1	F2	F3	F4	Total
Cardiac Patients	2	1	1	1	1	6
Diabetic Patients	26	17	5	3	17	68
Cardiac + Diabetic Patients	1	0	0	1	2	4
Cardiac + Hypertension Patients	1	0	1	2	1	5
Diabetes + Hypertension Patients	62	40	29	22	31	184
All Cardiac + Diabetic + Hypertension	8	6	2	1	0	17
Total	100	64	38	30	52	284

Cross-tabulation of liver stiffness stages against diagnostic categories revealed that patients with both diabetes and hypertension had the highest frequency across all fibrosis stages, notably with 16.8% in F4. Diabetic-only patients demonstrated a bimodal distribution, with peaks at F0 (38.2%) and F4 (25%). Cardiac patients and those with all three comorbidities displayed a more evenly spread profile across stages, though notably, the triple-comorbid group had no F4 cases.

Similar trends were observed in CAP scoring by diagnosis. Patients with diabetes and hypertension comprised the majority of S2 and S3 categories (25.4% and 13.6% of total cohort, respectively), reinforcing the significant association between metabolic disorders and hepatic steatosis. Diabetic-only

patients followed a similar distribution. Cardiac-only patients remained a minority with variable CAP scoring results, possibly due to underrepresentation in the sample. Descriptive data highlight a clinically significant pattern of increased liver fibrosis and steatosis in patients with coexisting diabetes and hypertension. Although no p-values were reported for intergroup differences, the stratification of SWE and CAP scores by diagnosis suggests strong associations between metabolic syndrome components and hepatic pathology. Notably, 28.9% of the cohort was classified with advanced fibrosis (F3–F4), a finding of public health relevance that emphasizes the need for early liver assessment in these populations.

Table 6. CAP Score by Diagnosis

Diagnosis	S0	S1	S2	S3	Total
Cardiac Patients	2	0	2	1	5
Diabetic Patients	9	17	25	17	68
Cardiac + Diabetic Patients	0	1	1	0	2
Cardiac + Hypertension Patients	1	2	2	0	5
Diabetes + Hypertension Patients	20	50	69	37	176
All Cardiac + Diabetic + Hypertension	3	5	3	5	16
Total	35	75	102	60	272

The diagnostic clustering observed in both Tables 5 and 6 supports the utility of SWE and CAP scoring in risk stratification and monitoring. While small subgroup sizes limited the statistical power for cardiac-only patients, the trends suggest that cardiac comorbidities may contribute to liver pathology when combined with diabetes or hypertension. These findings call for larger, inferential studies to quantify effect sizes and confirm statistical significance.

DISCUSSION

The present study demonstrates that Shear Wave Elastography (SWE) is a reliable and clinically valuable tool for staging liver fibrosis in patients with diabetes and cardiac conditions. The most notable finding was the high prevalence of advanced liver fibrosis (F3–F4) and moderate-to-severe hepatic steatosis (S2–S3) among individuals with both diabetes and hypertension. This pattern underscores the synergistic pathophysiological effects of metabolic disorders on hepatic architecture, possibly through mechanisms involving chronic systemic inflammation, insulin resistance, and microvascular injury that collectively stimulate fibrogenic pathways in the liver. The predominance of S2 steatosis and F0–F2 fibrosis stages in the general cohort reflects early yet detectable changes in hepatic tissue, which, if unaddressed, may progress to cirrhosis.

These findings are consistent with previous research by Deepthi Arun Kumar et al. (2024), who reported that approximately 30% of diabetic patients exhibited SWE values exceeding 13 kPa, indicative of significant liver fibrosis. Similarly, Trivedi et al. (2021) observed higher transient elastography and CAP scores in type 2 diabetic patients compared to non-diabetics (8.3 vs. 6.4 kPa; CAP: 322 vs. 296 dB/m), reinforcing the metabolic contribution to hepatic stiffening. Our data corroborate these findings by identifying comparable trends in a South Asian population, thereby expanding the geographical and ethnic relevance of SWE application. Furthermore, Sporea et al. (2016) reported that 18.8% of diabetic individuals with steatosis exhibited significant fibrosis (F2–F3) and 13.8% had cirrhosis (F4), a pattern paralleled by the 28.9% advanced fibrosis (F3–F4) rate in our study cohort (8). These results collectively affirm that diabetic populations are at increased risk for progressive liver disease and benefit from regular non-invasive screening.

Interestingly, while patients with cardiac disease alone constituted a small proportion of the cohort and did not exhibit a strong standalone association with advanced fibrosis, the combination of cardiac and diabetic pathology appeared to amplify the risk, with half of these patients showing cirrhotic-level stiffness (F4). Though our findings did not reach inferential statistical confirmation due to sample size constraints, they resonate with prior work by Nakayama et al. (2021), which highlighted that advanced heart failure (Stage D) is linked to elevated SWE values, suggesting hepatic congestion and dysfunction. This suggests that while early-stage cardiac conditions may not substantially affect liver stiffness, progression to decompensated cardiac function may exacerbate hepatic outcomes. Our findings thus support the inclusion of liver health assessments in the clinical monitoring of patients with overlapping metabolic and cardiovascular disorders.

From a clinical standpoint, the implications of early identification of hepatic fibrosis through SWE are significant. Given the non-invasive, rapid, and reproducible nature of this imaging modality, it offers an efficient alternative to liver biopsy, especially in settings where patient compliance or procedural risk is a concern. Early detection through SWE allows for the implementation of lifestyle interventions, glycemic control, antihypertensive therapy, and statin use—all of which have demonstrated benefits in slowing fibrosis progression. Furthermore, the integration of CAP scoring with SWE enhances diagnostic precision by concurrently evaluating steatosis, a key driver of non-alcoholic steatohepatitis (NASH), which remains a leading cause of liver transplantation in the Western world and is increasingly prevalent in South Asia.

Despite the strengths of this study, including a well-defined patient population, standardized SWE protocol, and comprehensive diagnostic stratification, certain limitations must be acknowledged. The study was conducted in a single tertiary care clinic, limiting the generalizability of the findings to broader or rural populations. Additionally, while SWE and CAP offer quantitative insights, the absence of confirmatory histopathology (liver biopsy) precludes validation of the fibrosis stages. The cross-sectional design restricts the ability to infer causality or disease progression over time. Moreover, the

relatively small number of cardiac-only and triple-comorbidity patients reduced the statistical power to detect subgroup differences and may have underestimated associations in those categories. Nevertheless, the findings provide a foundational understanding for future multicenter, longitudinal studies.

Given the growing burden of metabolic diseases globally, particularly in low-to-middle-income countries, this study advocates for the integration of SWE into routine screening protocols for high-risk patients. Future research should focus on evaluating longitudinal outcomes of SWE-detected fibrosis and the impact of targeted interventions. In addition, exploration of SWE's predictive validity in combination with biochemical markers and clinical scoring systems could enhance its role in comprehensive hepatic risk stratification. Ultimately, incorporating non-invasive liver assessment tools like SWE into routine diabetic and cardiometabolic care may significantly reduce the burden of undiagnosed liver disease and improve patient outcomes through timely interventions.

CONCLUSION

This study underscores the critical role of Shear Wave Elastography (SWE) in staging liver fibrosis among patients with diabetes and cardiac conditions, revealing a high prevalence of advanced fibrosis and steatosis, particularly in individuals with concurrent diabetes and hypertension. These findings highlight SWE's value as a non-invasive, accurate, and clinically feasible tool for early detection of hepatic fibrosis, offering a promising alternative to liver biopsy in routine assessments of high-risk metabolic populations. Incorporating SWE into standard care protocols may facilitate timely interventions, reduce progression to cirrhosis, and improve long-term hepatic outcomes. Clinically, this supports a multidisciplinary approach to managing patients with cardiometabolic disorders, while future research should explore longitudinal SWE monitoring and its integration with biochemical and lifestyle-modification strategies to enhance liver disease prevention and management.

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