Original Article

Correlation of Ultrasonographic Grading of Fatty Liver with Glycemic Control, Lipid Profile, and Liver Function Tests in Patients with Type 2 Diabetes Mellitus: A Cross-Sectional Study

Kranthikiran Thota[1], Sravani Kesidi[2]

[1]Assistant Professor, Department of General Medicine, Mamata Medical College, Khammam, Telangana, India. [2]Assistant Professor, Department of Radiodiagnosis, Mamata Medical College, Khammam, Telangana, India.

Abstract

Background: Fatty liver disease is a common hepatic manifestation of metabolic dysfunction in patients with type 2 diabetes mellitus (T2DM). Its severity may be associated with poor glycemic control, dyslipidemia, and altered liver function parameters. Aim of the study was to assess the correlation between ultrasonographic grading of fatty liver and glycemic control, lipid profile, and liver function tests in patients with T2DM. **Material and Methods:** This hospital-based cross-sectional study included 100 patients with T2DM at Mamata Medical College and Hospital, Khammam. Patients underwent clinical assessment, biochemical investigations, and abdominal ultrasonography. Hepatic steatosis was classified into Grades 0–III. Associations were analyzed using appropriate statistical tests and Spearman's correlation coefficient. **Results:** Fatty liver was identified in 80% of patients, with Grade I, II, and III steatosis observed in 38%, 29%, and 13%, respectively. Increasing fatty liver grades demonstrated significant positive correlations with HbA1c (ρ=0.628), fasting blood glucose (ρ=0.684), postprandial blood glucose (ρ=0.693), triglycerides (ρ=0.611), BMI (ρ=0.590), and ALT (ρ=0.605), all $p<0.001$. HDL cholesterol showed a significant negative correlation (ρ=−0.293, p=0.003). **Conclusion:** Increasing ultrasonographic fatty liver severity was associated with poorer glycemic control, hypertriglyceridemia, increased BMI, and elevated liver transaminases. Combined ultrasonographic and biochemical assessment may facilitate identification of patients with greater hepatic steatosis.

Keywords: Type 2 diabetes mellitus, Fatty liver, Ultrasonography, Glycemic control, HbA1c, Dyslipidemia, Liver function tests.

Received: 01 October 2026 **Revised: 20 October 2026** **Accepted: 02 November 2026** **Published: 09 November 2026**

Introduction

Metabolic dysfunction-associated steatotic liver disease (MASLD), previously termed non-alcoholic fatty liver disease (NAFLD), is one of the most prevalent chronic liver disorders worldwide and is closely associated with type 2 diabetes mellitus (T2DM), obesity, insulin resistance, and dyslipidemia. A recent meta-analysis by Amini-Salehi et al. reported a global NAFLD prevalence of approximately 30.2%, highlighting its considerable public health burden.[1] Cho et al. demonstrated that nearly 65% of patients with T2DM had NAFLD, with a substantial proportion exhibiting clinically significant hepatic fibrosis.[2] The coexistence of diabetes and hepatic steatosis increases the likelihood of progressive liver disease, cardiovascular complications, and metabolic deterioration.[3]

The pathophysiological relationship between T2DM and fatty liver is primarily mediated by insulin resistance, increased hepatic free fatty acid influx, enhanced de novo lipogenesis, and impaired lipid oxidation. Persistent hyperglycemia and associated dyslipidemia contribute to hepatic triglyceride accumulation, oxidative stress, and hepatocellular injury. Ultrasonography remains a widely accessible, non-invasive, and cost-effective imaging modality for detecting hepatic steatosis. Fatty liver is conventionally classified into mild (Grade I), moderate (Grade II), and severe (Grade III) categories based on hepatic echogenicity, posterior beam attenuation, and visualization of intrahepatic vessels and the diaphragm. However, ultrasonography has limited sensitivity for mild steatosis and cannot reliably identify inflammation or fibrosis.[4,5]

Previous investigations have demonstrated associations between fatty liver and metabolic abnormalities in diabetic populations. Almahmoud et al. reported an 80.4% prevalence of ultrasonographically detected fatty liver among Jordanian patients with T2DM, with elevated triglycerides, reduced high-density lipoprotein cholesterol, and increased liver transaminases showing significant associations.[6] Wang et al. demonstrated an association between glycated albumin-to-HbA1c ratio and fatty liver in 7,117 diabetic patients.[7] Similarly, Mukherjee et al.

Address for correspondence: Dr. Kranthikiran Thota, Assistant Professor, Department of General Medicine, Mamata Medical College, Khammam, Telangana, India.
E-mail: kranthikiran.thota@gmail.com

DOI:
10.21276/amit.2026.v13.i3.1175

How to cite this article: Thota K, Kesidi S. Correlation of Ultrasonographic Grading of Fatty Liver with Glycemic Control, Lipid Profile, and Liver Function Tests in Patients with Type 2 Diabetes Mellitus: A Cross-Sectional Study. Acta Med Int. 2026;13(3):942-948.

identified significant relationships between hepatic steatosis and anthropometric and lipid parameters among newly diagnosed Indian diabetic patients.[8] Hadadi et al. observed a significantly greater prevalence of MASLD among patients with uncontrolled diabetes.[9] More recently, Semeya et al. identified poor glycemic control, dyslipidemia, and altered liver enzymes as important predictors of fatty liver among Egyptian patients with T2DM.[10]

Despite these findings, the relationship between increasing ultrasonographic grades of hepatic steatosis and simultaneous alterations in glycemic indices, individual lipid parameters, and liver function tests remains insufficiently characterized across different diabetic populations. Many studies primarily evaluate the presence or absence of fatty liver rather than grade-wise biochemical correlations. Therefore, the present cross-sectional study aims to assess the correlation of ultrasonographic fatty liver grading with glycemic control, lipid profile, and liver function tests in patients with T2DM, thereby evaluating the potential clinical utility of routine biochemical markers in identifying patients with more pronounced hepatic steatosis.

Materials and Methods

The present study was designed as a hospital-based, observational, cross-sectional study conducted in the Department of General Medicine in collaboration with the Department of Radiology at Mamata Medical College and Hospital, Khammam, Telangana, India. The study aimed to evaluate the correlation between ultrasonographic grading of fatty liver and glycemic control, lipid profile, and liver function tests among patients diagnosed with type 2 diabetes mellitus (T2DM). A total of 100 patients with T2DM attending the General Medicine outpatient department or admitted to the inpatient wards were included in the study. Eligible patients were selected according to predefined inclusion and exclusion criteria. Clinical history, anthropometric measurements, laboratory investigations, and abdominal ultrasonographic findings were recorded using a structured data collection proforma. The severity of hepatic steatosis was classified into Grade I, Grade II, and Grade III based on ultrasonographic characteristics, and its association with biochemical parameters was analyzed.

Sample Size

The study included a total of 100 patients diagnosed with type 2 diabetes mellitus. The sample size was selected based on the feasibility of patient recruitment, availability of eligible participants, and study duration.

Inclusion Criteria

1. Patients aged 18 years and above.
2. Patients diagnosed with type 2 diabetes mellitus according to the American Diabetes Association diagnostic criteria.
3. Patients with an established history of T2DM, irrespective of disease duration.
4. Patients willing to undergo abdominal ultrasonography and the required biochemical investigations.
5. Patients providing written informed consent to participate in the study.

Exclusion Criteria

1. Patients with type 1 diabetes mellitus or gestational diabetes mellitus.
2. Patients with significant alcohol consumption (more than 20 g/day in women or 30 g/day in men).
3. Patients with known chronic liver diseases, including viral hepatitis B or C, autoimmune hepatitis, and cirrhosis of other established etiologies.
4. Patients receiving medications known to cause hepatic steatosis, such as long-term corticosteroids, amiodarone, or methotrexate.
5. Patients with known hepatocellular carcinoma or other hepatic malignancies.
6. Pregnant and lactating women.
7. Patients with severe systemic illness or conditions preventing completion of the required investigations.
8. Patients unwilling to participate or provide informed consent.

Study Tools

- **Structured proforma:** Used to document demographic details, clinical history, duration of diabetes, medication history, and associated comorbidities.
- **Anthropometric assessment:** Height, weight, body mass index (BMI), and waist circumference were recorded.
- **Glycemic parameters:** Fasting blood glucose (FBS), postprandial blood glucose (PPBS), and glycated hemoglobin (HbA1c).
- **Lipid profile:** Total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and very-low-density lipoprotein cholesterol (VLDL-C).
- **Liver function tests:** Serum alanine aminotransferase (ALT/SGPT), aspartate aminotransferase (AST/SGOT), alkaline phosphatase (ALP), total bilirubin, direct bilirubin, total protein, and serum albumin.
- **Ultrasonography:** Abdominal ultrasonography was performed to assess hepatic echogenicity, hepatorenal echogenicity contrast, posterior acoustic attenuation, and visualization of intrahepatic vascular structures.
- **Ultrasonographic grading of fatty liver:**
  - Grade 0 (normal): Normal hepatic echogenicity with clear visualization of intrahepatic vessels and the diaphragm.
  - Grade I (mild): Slight diffuse increase in hepatic echogenicity with preserved visualization of intrahepatic vessels and the diaphragm.
  - Grade II (moderate): Moderate increase in hepatic echogenicity with mildly impaired visualization of intrahepatic vessels and the diaphragm.
  - Grade III (severe): Marked increase in hepatic echogenicity with poor visualization of intrahepatic vessels, posterior liver segments, and the diaphragm.

Data Collection Procedure

1. Patient recruitment: Patients with established T2DM attending the General Medicine outpatient department or admitted to the inpatient wards were screened for eligibility.
2. Clinical assessment: Detailed medical history, duration of diabetes, antidiabetic treatment, alcohol consumption, associated hypertension, and other comorbidities were recorded.
3. Anthropometric measurements: Height and weight were

measured, and BMI was calculated as weight in kilograms divided by height in meters squared.

4. Blood sample collection: Venous blood samples were collected after an overnight fast of 8–12 hours to assess fasting blood glucose, lipid profile, and liver function parameters.
5. Assessment of glycemic control: HbA1c was measured to evaluate long-term glycemic control. Patients were categorized as having controlled diabetes (HbA1c <7%) or uncontrolled diabetes (HbA1c ≥7%) for comparative analysis.
6. Ultrasonographic evaluation: Abdominal ultrasonography was performed by the Department of Radiology using a standard ultrasound machine with a curvilinear transducer. Hepatic steatosis was graded from 0 to III based on standard sonographic criteria.
7. Correlation assessment: Ultrasonographic grades were correlated with HbA1c, fasting and postprandial blood glucose, lipid parameters, and liver function tests.
8. Data documentation: Clinical, biochemical, and ultrasonographic findings were entered into a structured proforma and subsequently compiled for statistical analysis.

Statistical Analysis: The collected data were entered into Microsoft Excel and analyzed using SPSS statistical software Version 23.0. Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range, depending on data distribution, while categorical variables were presented as frequencies and percentages. Comparisons of continuous biochemical parameters across ultrasonographic fatty liver grades were performed using one-way analysis of variance (ANOVA) or the Kruskal–Wallis test, as appropriate. Associations between categorical variables were evaluated using the Chi-square test or Fisher's exact test. Spearman's rank correlation coefficient was used to assess relationships between ordinal ultrasonographic grades and glycemic parameters, lipid profile, and liver function tests. Multivariable ordinal logistic regression could be performed to assess independent associations after adjustment for relevant confounding factors. A p-value <0.05 was considered statistically significant.

Results

Table 1: Distribution of Demographic, Anthropometric, and Clinical Characteristics Among Patients With Type 2 Diabetes Mellitus (N = 100)

Parameter	Category	Number (n)	Percentage (%)
Age (years)	18–30	0	0
	31–40	13	13
	41–50	37	37
	51–60	34	34
	>60	16	16
Gender	Male	50	50
	Female	50	50
BMI (kg/m²)	<23	30	30
	23–24.9	19	19
	≥25	51	51
Duration of diabetes	<5 years	48	48
	5–10 years	39	39
	>10 years	13	13
Hypertension	Present	42	42
	Absent	58	58
Glycemic control	HbA1c <7%	31	31
	HbA1c ≥7%	69	69

The study population comprised 100 patients with type 2 diabetes mellitus, with the majority belonging to the age groups of 41–50 years (37%) and 51–60 years (34%). There was an equal distribution of males and females, with each accounting for 50% of participants. Regarding anthropometric characteristics, 51% had a BMI of ≥25 kg/m², indicating a considerable burden of obesity according to Asian BMI thresholds. Nearly half of the patients (48%) had a diabetes duration of less than five years, whereas 13% had diabetes for more than ten years. Hypertension was observed in 42% of participants, indicating frequent coexistence of cardiometabolic risk factors. Poor glycemic control, defined as HbA1c ≥7%, was observed in 69% of patients, highlighting the substantial proportion with inadequately controlled diabetes.

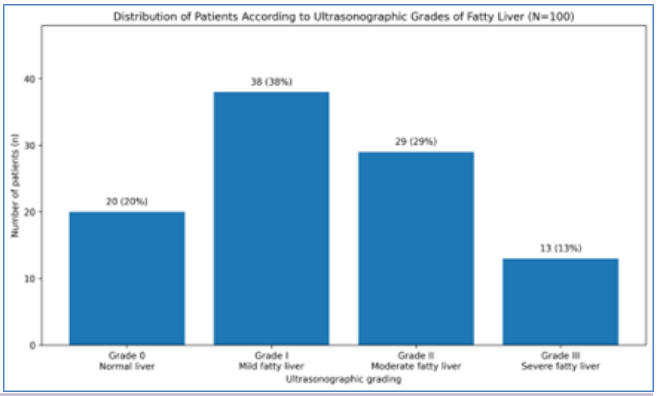


Figure 1: Distribution of Patients According to Ultrasonographic Grades of Fatty Liver (N = 100)

Ultrasonographic examination revealed fatty liver in 80% of

patients with type 2 diabetes mellitus, while 20% demonstrated normal hepatic echogenicity. Grade I fatty liver was the most frequently observed category, accounting for 38% of patients, followed by Grade II in 29%. Severe hepatic steatosis (Grade III) was identified in 13% of participants. Moderate-to-severe fatty liver (Grades II and III) was present in 42% of the study population, indicating a substantial burden of advanced ultrasonographic steatosis. The distribution demonstrates that hepatic fat accumulation is common among patients with T2DM, with mild steatosis representing the largest individual category. These findings emphasize the importance of evaluating hepatic steatosis in diabetic patients, particularly those with associated metabolic abnormalities.

Table 2: Comparison of Glycemic Parameters Across Different Ultrasonographic Grades of Fatty Liver

Glycemic parameter	Grade 0 (n=20)	Grade I (n=38)	Grade II (n=29)	Grade III (n=13)	p-value
FBS (mg/dL)	107.90 ± 26.23	136.88 ± 32.49	174.63 ± 29.76	193.82 ± 37.44	<0.001
PPBS (mg/dL)	156.89 ± 33.04	205.44 ± 31.80	223.37 ± 33.51	279.07 ± 28.35	<0.001
HbA1c (%)	6.56 ± 0.68	7.34 ± 0.85	7.90 ± 0.69	8.61 ± 0.87	<0.001
Duration of diabetes (years)	4.45 ± 3.15	3.74 ± 3.47	6.55 ± 3.20	9.33 ± 4.54	<0.001

A statistically significant association was observed between ultrasonographic fatty liver grades and glycemic parameters. Mean fasting blood glucose increased from 107.90 ± 26.23 mg/dL in Grade 0 to 193.82 ± 37.44 mg/dL in Grade III, with a significant difference across groups (p<0.001). Similarly, mean postprandial blood glucose increased progressively from 156.89 ± 33.04 mg/dL to 279.07 ± 28.35 mg/dL (p<0.001). Mean HbA1c showed a consistent increase from 6.56 ± 0.68% in patients without fatty liver to 8.61 ± 0.87% in those with severe fatty liver (p<0.001). Duration of diabetes also differed significantly across grades, with the longest mean duration observed in Grade III patients. These findings demonstrate a strong association between worsening glycemic status and increasing ultrasonographic severity of hepatic steatosis.

Table 3: Comparison of Lipid Profile Parameters Across Different Ultrasonographic Grades of Fatty Liver

Lipid parameter	Grade 0 (n=20)	Grade I (n=38)	Grade II (n=29)	Grade III (n=13)	p-value
Total cholesterol (mg/dL)	170.99 ± 29.24	178.09 ± 29.59	181.67 ± 25.57	209.78 ± 29.24	0.009
Triglycerides (mg/dL)	132.06 ± 49.31	162.36 ± 44.99	211.62 ± 58.15	249.80 ± 45.49	<0.001
LDL cholesterol (mg/dL)	96.75 ± 26.26	102.52 ± 35.45	98.55 ± 21.86	119.70 ± 34.78	0.203
HDL cholesterol (mg/dL)	45.77 ± 9.11	46.29 ± 8.36	41.30 ± 9.05	39.07 ± 9.00	0.009
VLDL cholesterol (mg/dL)	26.41 ± 9.86	32.47 ± 9.00	42.32 ± 11.63	49.96 ± 9.10	<0.001

Comparison of lipid parameters across ultrasonographic grades demonstrated significant metabolic abnormalities with increasing fatty liver severity. Mean total cholesterol increased from 170.99 ± 29.24 mg/dL in Grade 0 to 209.78 ± 29.24 mg/dL in Grade III (p=0.009). A marked increase in triglyceride levels was observed, rising from 132.06 ± 49.31 mg/dL to 249.80 ± 45.49 mg/dL (p<0.001). HDL cholesterol levels were lower in patients with higher grades of fatty liver, with a significant difference across groups (p=0.009). VLDL cholesterol also increased significantly with increasing ultrasonographic severity (p<0.001). Although mean LDL cholesterol was highest in Grade III, the differences across groups were not statistically significant (p=0.203). These findings suggest that hypertriglyceridemia and reduced HDL cholesterol are prominent lipid abnormalities associated with increasing hepatic steatosis.

Table 4: Comparison of Liver Function Test Parameters Across Different Ultrasonographic Grades of Fatty Liver

Liver function parameter	Grade 0 (n=20)	Grade I (n=38)	Grade II (n=29)	Grade III (n=13)	p-value
ALT/SGPT (U/L)	23.98 ± 12.73	38.56 ± 12.40	44.15 ± 9.63	56.79 ± 10.94	<0.001
AST/SGOT (U/L)	22.03 ± 8.67	30.64 ± 10.51	32.75 ± 7.63	38.69 ± 13.22	<0.001
ALP (U/L)	88.72 ± 16.80	95.45 ± 22.19	98.00 ± 25.28	102.85 ± 21.93	0.226
Total bilirubin (mg/dL)	0.67 ± 0.13	0.68 ± 0.18	0.77 ± 0.20	0.75 ± 0.18	0.181
Direct bilirubin (mg/dL)	0.19 ± 0.06	0.18 ± 0.05	0.20 ± 0.06	0.19 ± 0.06	0.387
Total protein (g/dL)	7.16 ± 0.39	7.08 ± 0.47	7.07 ± 0.38	6.79 ± 0.40	0.105
Serum albumin (g/dL)	4.33 ± 0.25	4.37 ± 0.34	4.15 ± 0.27	4.17 ± 0.35	0.020
AST/ALT ratio	1.27 ± 0.91	0.92 ± 0.56	0.76 ± 0.20	0.70 ± 0.22	0.270

Liver function test parameters demonstrated significant differences in serum transaminase concentrations across ultrasonographic grades of fatty liver. Mean ALT levels increased progressively from 23.98 ± 12.73 U/L in Grade 0 to 56.79 ± 10.94 U/L in Grade III (p<0.001). Similarly, AST levels increased from 22.03 ± 8.67 U/L to 38.69 ± 13.22 U/L, demonstrating a statistically significant difference (p<0.001). Serum albumin levels also differed significantly across grades (p=0.020), although a consistent progressive decline was not observed. In contrast, ALP, total bilirubin, direct bilirubin, total protein, and AST/ALT ratio did not demonstrate statistically significant intergroup differences. The findings indicate that ALT and AST are associated with increasing ultrasonographic hepatic steatosis, whereas other routine liver biochemical parameters show comparatively weaker associations.

Table 5: Spearman's Rank Correlation Between Ultrasonographic Fatty Liver Grades and Glycemic, Anthropometric, and Lipid Parameters Among Patients With Type 2 Diabetes Mellitus (N = 100)

Parameter	Spearman's ρ	p-value
Fasting blood glucose	0.684	<0.001
Postprandial blood glucose	0.693	<0.001
HbA1c	0.628	<0.001
Duration of diabetes	0.388	<0.001
Body mass index	0.590	<0.001
Total cholesterol	0.275	0.006
Triglycerides	0.611	<0.001
LDL cholesterol	0.122	0.225
HDL cholesterol	−0.293	0.003
VLDL cholesterol	0.611	<0.001

Spearman's rank correlation analysis demonstrated significant positive correlations between ultrasonographic fatty liver grades and several metabolic parameters. Postprandial blood glucose exhibited the strongest correlation with fatty liver grading (ρ=0.693, p<0.001), followed by fasting blood glucose (ρ=0.684, p<0.001) and HbA1c (ρ=0.628, p<0.001). Triglycerides also demonstrated a significant positive correlation (ρ=0.611, p<0.001), indicating higher triglyceride concentrations with increasing hepatic steatosis. BMI showed a positive correlation (ρ=0.590, p<0.001), whereas duration of diabetes demonstrated a weaker but statistically significant association (ρ=0.388, p<0.001). HDL cholesterol was negatively correlated with fatty liver grading (ρ=−0.293, p=0.003), while LDL cholesterol showed no statistically significant association (p=0.225). These findings identify glycemic parameters, triglycerides, and BMI as important correlates of ultrasonographic fatty liver severity in patients with T2DM.

Table 6: Spearman's Rank Correlation Between Ultrasonographic Fatty Liver Grades and Liver Function Test Parameters Among Patients With Type 2 Diabetes Mellitus (N = 100)

Liver function parameter	Spearman's ρ	p-value	Direction
ALT/SGPT	0.605	<0.001	Positive
AST/SGOT	0.390	<0.001	Positive
ALP	0.201	0.045	Positive
Total bilirubin	0.194	0.053	Positive
Direct bilirubin	0.054	0.596	Positive
Total protein	−0.203	0.043	Negative
Serum albumin	−0.256	0.010	Negative
AST/ALT ratio	−0.199	0.048	Negative

Correlation analysis demonstrated a significant positive association between ultrasonographic fatty liver grades and serum ALT levels (ρ=0.605, p<0.001), representing the strongest correlation among liver biochemical parameters. Serum AST also exhibited a statistically significant positive correlation (ρ=0.390, p<0.001), although its association was weaker than that of ALT. ALP demonstrated a weak positive correlation (ρ=0.201, p=0.045), whereas total bilirubin and direct bilirubin did not show statistically significant correlations. Serum albumin exhibited a weak negative correlation with fatty liver grading (ρ=−0.256, p=0.010), suggesting lower albumin concentrations in patients with more severe steatosis. Total protein and AST/ALT ratio also demonstrated weak negative correlations, with p-values of 0.043 and 0.048, respectively. Overall, ALT exhibited the most prominent biochemical association with increasing fatty liver severity, followed by AST, suggesting that transaminases are more closely related to ultrasonographic steatosis than the other liver function parameters evaluated.

Discussion

Metabolic dysfunction-associated steatotic liver disease (MASLD) is increasingly recognized as an important hepatic manifestation of metabolic dysfunction in patients with type 2 diabetes mellitus (T2DM). The present analysis evaluated the relationship between ultrasonographic grading of fatty liver and glycemic control, lipid abnormalities, and liver function parameters among 100 patients with T2DM. Hepatic steatosis was identified in 80% of patients, with Grade I, II, and III fatty liver observed in 38%, 29%, and 13%, respectively. Significant associations were demonstrated between increasing ultrasonographic grades and elevated glycemic indices, triglycerides, body mass index (BMI), and liver transaminases, highlighting the close relationship between hepatic steatosis and metabolic disturbances.

The high prevalence of fatty liver is consistent with observations from Indian diabetic populations. Gupta et al. (2021), in a cross-sectional study involving 250 North Indian patients with T2DM, reported a substantial burden of hepatic steatosis and fibrosis. Grade III steatosis was identified in 85.2% of their study population, with BMI and serum alanine aminotransferase (ALT) emerging as significant predictors of hepatic steatosis. Their investigation also demonstrated associations between longer diabetes duration, obesity, and hepatic fibrosis.[11] Although the distribution of steatosis severity differed considerably, both investigations emphasize the importance of hepatic assessment in diabetic patients. Differences in participant characteristics, imaging-based classification, and recruitment settings may explain variations in severity distribution.

Glycemic control demonstrated a significant relationship with ultrasonographic fatty liver grading. Mean HbA1c increased progressively from 6.56 ± 0.68% in Grade 0 to 8.61 ± 0.87% in Grade III ($p<0.001$). Similarly, fasting and postprandial blood glucose increased significantly with steatosis severity. Spearman's correlation analysis demonstrated positive correlations between fatty liver grading and HbA1c ($\rho=0.628$), fasting glucose ($\rho=0.684$), and postprandial glucose ($\rho=0.693$), all with $p<0.001$. Colosimo et al. (2023), in a longitudinal analysis of 637 patients with T2DM, demonstrated that improvements in glycemic control were associated with reductions in fatty liver index, independently of changes in BMI and glucose-lowering medication class.[12] These observations support the relationship between glucose metabolism and hepatic fat accumulation, although the cross-sectional nature of the present analysis does not establish causality.

The relationship between fatty liver severity and duration of diabetes was also significant ($\rho=0.388$, $p<0.001$). Patients with Grade III steatosis had a mean diabetes duration of 9.33 ± 4.54 years, compared with 4.45 ± 3.15 years among those with normal ultrasonographic findings. Prolonged metabolic exposure, insulin resistance, and persistent hyperglycemia may contribute to progressive hepatic lipid accumulation. However, diabetes duration alone cannot reliably predict the severity of hepatic disease, as obesity, treatment-related factors, and individual metabolic susceptibility may influence steatosis development.

Lipid profile abnormalities demonstrated an important relationship with fatty liver severity. Mean triglyceride concentrations increased from 132.06 ± 49.31 mg/dL in Grade 0 to 249.80 ± 45.49 mg/dL in Grade III ($p<0.001$). Triglycerides exhibited a significant positive correlation with steatosis grading ($\rho=0.611$, $p<0.001$), whereas HDL cholesterol demonstrated a negative correlation ($\rho=-0.293$, $p=0.003$). Total cholesterol also showed a significant positive correlation, while LDL cholesterol was not significantly associated with steatosis severity. These findings suggest that hypertriglyceridemia and reduced HDL cholesterol are more consistently associated with hepatic fat accumulation than LDL cholesterol concentration.

Shen et al. (2024) evaluated ultrasound-guided attenuation parameters, liver steatosis analysis, and hepatorenal index for assessing hepatic fat severity. Their investigation demonstrated strong correlations between quantitative attenuation measurements and controlled attenuation parameter values, supporting the usefulness of ultrasound-based techniques for evaluating hepatic steatosis.[13] Although their investigation primarily addressed imaging performance rather than biochemical associations, it supports the importance of objective assessment of hepatic fat severity.

Liang et al. (2025) investigated 4,663 elderly individuals and identified significant associations between ultrasonographic steatosis severity and BMI, fasting glucose, triglycerides, ALT, and AST.[14] These findings closely correspond with the present correlations involving BMI ($\rho=0.590$), fasting glucose ($\rho=0.684$), triglycerides ($\rho=0.611$), and ALT ($\rho=0.605$). The consistency of these metabolic relationships across different populations reinforces the importance of metabolic dysfunction in hepatic steatosis.

Regarding liver function parameters, serum ALT and AST increased significantly across ultrasonographic grades ($p<0.001$). ALT demonstrated a stronger correlation with steatosis severity ($\rho=0.605$) than AST ($\rho=0.390$). Serum albumin demonstrated a weaker negative association, while bilirubin parameters showed no significant correlation. Hao et al. (2025), in a study involving 239 patients with T2DM, demonstrated positive associations of ultrasound attenuation imaging measurements with BMI, glucose, ALT, triglycerides, and steatosis grade, together with a negative association with HDL cholesterol.[15] These observations closely correspond with the biochemical relationships identified in the present analysis.

The clinical interpretation of conventional ultrasonographic grades nevertheless requires caution. Hamadouche et al. (2025) demonstrated that ultrasound hepatorenal index measurements could identify hepatic steatosis in patients with T2DM but exhibited reduced diagnostic performance when differentiating higher grades of steatosis.[16] Furthermore, conventional ultrasonography cannot reliably distinguish uncomplicated steatosis from steatohepatitis or determine fibrosis severity. Consequently, biochemical abnormalities and ultrasound grading should be interpreted together, with appropriate fibrosis risk assessment when clinically indicated.

The principal limitations include the cross-sectional design, relatively small study population, and reliance on ultrasonographic grading rather than quantitative hepatic fat measurement. The absence of multivariable adjustment also prevents determination of whether glycemic control, triglycerides, BMI, and liver enzymes are independently associated with steatosis severity. Nevertheless, the analysis demonstrates the clinical relevance of evaluating glycemic indices, lipid abnormalities, and liver biochemical parameters together when assessing hepatic steatosis in patients with T2DM.

Conclusion

The present analysis demonstrated a high prevalence of ultrasonographically detected fatty liver among patients with type 2 diabetes mellitus, with increasing steatosis severity associated with poorer glycemic control, elevated triglycerides, increased BMI, and higher serum transaminase concentrations. HbA1c, fasting and postprandial blood glucose, triglycerides, and ALT showed particularly significant positive correlations with ultrasonographic fatty liver grading, whereas HDL cholesterol demonstrated a significant negative correlation. These findings suggest that routine metabolic and biochemical investigations, combined with abdominal ultrasonography, may help identify diabetic patients with more pronounced hepatic steatosis. However, these parameters cannot independently establish steatohepatitis or hepatic fibrosis. Further prospective studies involving larger populations, quantitative imaging, and appropriate confounder adjustment are required to clarify the independent metabolic determinants and clinical progression of fatty liver disease in patients with T2DM.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Amini-Salehi E, Letafatkar N, Norouzi N, et al. Global prevalence of nonalcoholic fatty liver disease: an updated review meta-analysis comprising a population of 78 million from 38 countries. Arch Med Res. 2024;55(6):103043. DOI: 10.1016/j.arcmed.2024.103043. PMID: 39094335.
2. Cho EEL, Ang CZ, Quek J, et al. Global prevalence of non-alcoholic fatty liver disease in type 2 diabetes mellitus: an updated systematic review and meta-analysis. Gut. 2023;72(11):2138–2148. DOI: 10.1136/gutjnl-2023-330110. PMID: 37491159.
3. Younossi ZM, Golabi P, Price JK, Owrangi S, Gundu-Rao N, Satchi R, Paik JM. The global epidemiology of nonalcoholic fatty liver disease and nonalcoholic steatohepatitis among patients with type 2 diabetes. Clin Gastroenterol Hepatol. 2024;22(10):1999–2010.e8. DOI: 10.1016/j.cgh.2024.03.006. PMID: 38521116.
4. Rinella ME, Neuschwander-Tetri BA, Siddiqui MS, Abdelmalek MF, Caldwell S, Barb D, Kleiner DE, Loomba R. AASLD practice guidance on the clinical assessment and management of nonalcoholic fatty liver disease. Hepatology. 2023;77(5):1797–1835. DOI: 10.1097/HEP.0000000000000323. PMID: 36727674.
5. European Association for the Study of the Liver (EASL), European Association for the Study of Diabetes (EASD), European Association for the Study of Obesity (EASO). EASL-EASD-EASO clinical practice guidelines on the management of metabolic dysfunction-associated steatotic liver disease (MASLD). J Hepatol. 2024;81(3):492–542.
6. Almahmoud MH, Al Khawaja NM, Alkinani A, Khader Y, Ajlouni KM. Prevalence of fatty liver disease and its associated factors among Jordanian patients with type 2 diabetes mellitus: a cross-sectional study. Ann Med Surg (Lond). 2021;68:102677. DOI: 10.1016/j.amsu.2021.102677. PMID: 34401141.
7. Wang JW, Jin CH, Ke JF, et al. GA/HbA1c ratio is a simple and practical indicator to evaluate the risk of metabolic dysfunction-associated fatty liver disease in type 2 diabetes: an observational study. Diabetol Metab Syndr. 2022.
8. Mukherjee S, Mukherjee S, Kwok CS, Phillips A. Correlation between non-alcoholic fatty liver disease and metabolic parameters in persons with newly diagnosed type 2 diabetes mellitus. World J Hepatol. 2024;16(8):1120–1130.
9. Hadadi I, Adam M, Musa MJ, Gareeballah A, Alqahtani M, Kanbayti I, Hazazi A. Exploring the prevalence and coexistence of metabolic dysfunction-associated steatotic liver disease in type 2 diabetes mellitus patients using ultrasound: a cross-sectional study. Curr Med Imaging. 2025;21:e15734056354807.
10. Semeya AA, Abdel Hafez RSA, Ewais SHM, Mostafa SM, Eldeeb A, Elgamal R, Othman AAA. Screening for metabolic-associated fatty liver disease in type 2 diabetes patients using non-invasive scores and ultrasound: a cross-sectional study in Egypt. BMC Gastroenterol. 2025;25(1):639. DOI: 10.1186/s12876-025-03844-9. PMID: 40954485.
11. Gupta A, Anoop S, Ansari IA, Prakash S, Misra A. High prevalence of hepatic steatosis and hepatic fibrosis in patients with type 2 diabetes mellitus. Clin Nutr ESPEN. 2021;46:519–526. doi: 10.1016/j.clnesp.2021.08.028. PMID: 34857244.
12. Colosimo S, Tan GD, Petroni ML, Marchesini G, Tomlinson JW. Improved glycaemic control in patients with type 2 diabetes has a beneficial impact on NAFLD, independent of change in BMI or glucose lowering agent. Nutr Metab Cardiovasc Dis. 2023;33(3):640–648. doi: 10.1016/j.numecd.2022.12.010. PMID: 36710114.
13. Shen Q, Hao Y, Chen J, Liu Q, Jia H, Liu L. Correlation and performance of three ultrasound techniques to stage hepatic steatosis in nonalcoholic fatty liver disease. Curr Med Imaging. 2024;20. doi: 10.2174/0115734056278434231213112035.
14. Liang Z, Huang R, Zhang L. Correlation between hepatic steatosis severity diagnosed by ultrasound and metabolic indexes in elderly patients with MAFLD. Front Med (Lausanne). 2025;11:1467773. Published January 7, 2025.
15. Hao Y, Zhang Y, Yin G, Zhang L, Liu L. Correlation between liver fat content determined by ultrasonic attenuation imaging and lipid metabolism in patients with non-alcoholic fatty liver disease. Curr Med Imaging. 2025;21. doi: 10.2174/0115734056335310250217064323. PMID: 40103469.
16. Hamadouche M, Vilgrain V, Hobeika C, et al. Ultrasound hepatorenal index for the diagnosis of steatosis in patients with type 2 diabetes: a prospective validation study. Eur Radiol. 2025;35(12):7927–7939. doi: 10.1007/s00330-025-11774-z. PMID: 40560415.