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Original Research Paper

Metabolic and Hepatic Alterations in Type 2 Diabetes Mellitus: A Cross-Sectional Analysis

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ABSTRACT:
Background: Type 2 Diabetes Mellitus (T2DM) is a global health challenge characterized by insulin resistance, hyperglycemia, and metabolic Dysregulation. T2DM is associated with lipid abnormalities and liver dysfunction, significantly increasing the risk of cardiovascular disease and non-alcoholic fatty liver disease (NAFLD). Understanding the interplay between glycemic control, lipid profile, and liver enzyme alterations is essential for better management of T2DM and its complications. **Objective:** To investigate the correlation between glycemic control (HbA1c), fasting lipid profile (total cholesterol, triglycerides, LDL, HDL), and liver enzyme levels (SGOT, SGPT) in T2DM patients attending a tertiary healthcare center. **Methods:** A cross-sectional study was conducted at Dr. M.K. Shah Medical College & Research Centre, Ahmedabad, including 125 T2DM patients. Patients with Type 1 DM, chronic alcoholism, and other hepatic disorders were excluded. Biochemical assessments included fasting blood sugar (FBS), HbA1c, fasting lipid profile, and liver function enzymes. Statistical analysis was performed using SPSS v20.0, applying chi-square tests and correlation analysis. A p-value of <0.05 was considered statistically significant. **Results:** Patients with poor glycemic control (HbA1c >8.0%) demonstrated a significantly higher prevalence of Dyslipidemia and liver enzyme elevation. Elevated HbA1c levels were strongly correlated with increased SGOT and SGPT values (p <0.05). Triglyceride and LDL levels were significantly higher in patients with poor glycemic control, while HDL levels were reduced. The prevalence of NAFLD was also higher in this group. Comparison with previous studies confirms similar trends, highlighting the metabolic burden in T2DM patients. **Conclusion:** The study establishes a strong association between poor glycemic control and metabolic disturbances in T2DM patients. Elevated HbA1c levels were linked to hepatic dysfunction and adverse lipid profiles, reinforcing the importance of regular screening and early intervention strategies. Comprehensive diabetes management should integrate liver function and lipid profile assessments to mitigate long-term complications.

Keywords: Type 2 Diabetes Mellitus, Glycemic Control, Lipid Profile, Liver Enzymes, NAFLD, Dyslipidemia, Cardiovascular Risk

INTRODUCTION:

Type 2 Diabetes Mellitus (T2DM) is a chronic, progressive metabolic disorder characterized by insulin resistance and relative insulin deficiency, leading to hyperglycemia and multiple organ dysfunctions. It is one of the leading causes of morbidity and mortality worldwide, with an estimated global prevalence of 10.5% among adults aged 20–79 years, affecting approximately 537 million individuals (1). The burden of T2DM is projected to rise, increasing the risk of cardiovascular diseases, neuropathy, nephropathy, and hepatic complications (2, 3).

The liver plays a crucial role in glucose metabolism, lipid regulation, and insulin sensitivity. Impaired hepatic function in T2DM is often associated with increased levels of liver enzymes, including alanine aminotransferase (ALT) and aspartate aminotransferase (AST), which serve as markers of hepatocellular injury (4). Elevated liver enzymes in T2DM patients have been correlated with increased insulin resistance, systemic

inflammation, and the development of non-alcoholic fatty liver disease (NAFLD) (5, 6). NAFLD, a hepatic manifestation of metabolic syndrome, affects nearly 70% of individuals with T2DM and can progress to non-alcoholic steatohepatitis (NASH), cirrhosis, and hepatocellular carcinoma if left untreated (7,8).

Dyslipidemia is a well-recognized complication of T2DM, characterized by elevated triglycerides, low high-density lipoprotein (HDL) cholesterol, and increased low-density lipoprotein (LDL) cholesterol, collectively contributing to an increased risk of atherosclerosis and cardiovascular diseases (9). The insulin-resistant state in T2DM promotes excessive hepatic very-low-density lipoprotein (VLDL) production, decreased clearance of triglyceride-rich lipoproteins, and abnormal fatty acid oxidation, leading to lipid imbalances (10, 11). Studies have shown that poor glycemic control, reflected by elevated HbA1c levels, exacerbates lipid abnormalities and further aggravates hepatic dysfunction (12, 13).

Research suggests that chronic hyperglycemia triggers oxidative stress and pro-inflammatory cytokine release, contributing to hepatocyte injury and worsening metabolic outcomes (14). Elevated levels of tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6) have been observed in T2DM patients with hepatic dysfunction, further supporting the link between systemic inflammation and liver injury (15, 16). Additionally, the interplay between hyperglycemia, insulin resistance, and altered lipid metabolism exacerbates endothelial dysfunction, increasing cardiovascular risk in these patients (17).

Several epidemiological studies have demonstrated a strong correlation between poor glycemic control and hepatic dysfunction. A study by Targher et al. (2010) highlighted that T2DM patients with higher HbA1c levels exhibited significantly elevated liver enzyme levels and a higher prevalence of NAFLD (18). Similarly, a meta-analysis by Yki-Järvinen (2016) confirmed that ALT and AST levels were independent predictors of insulin resistance and metabolic syndrome in diabetic patients (19). Findings from Lee et al. (2021) further supported this association, demonstrating that T2DM patients with uncontrolled hyperglycemia had a significantly higher risk of developing hepatic fibrosis (20).

Despite growing evidence, routine assessment of liver function tests (LFTs) and lipid profiles in T2DM patients is often overlooked in clinical practice. Early detection and management of metabolic dysfunctions through lifestyle interventions, glycemic control, and pharmacological approaches can significantly reduce the risk of liver-related complications (21). Current treatment strategies include weight management, the use of insulin sensitizers (e.g., metformin, thiazolidinediones), lipid-lowering agents (e.g., statins, fibrates), and hepatoprotective therapies (22, 23).

In conclusion, understanding the bidirectional relationship between glycemic control, lipid metabolism, and hepatic function is essential for optimizing diabetes management. This study aims to explore the correlation between HbA1c levels, lipid abnormalities, and liver enzyme alterations in T2DM patients, providing valuable insights for clinicians in mitigating metabolic and hepatic complications.

OBJECTIVES:

The primary objective of this study is to evaluate the impact of glycemic control on lipid profile and liver enzyme levels in T2DM patients. Secondary objectives include assessing the prevalence of dyslipidemia and hepatic dysfunction and comparing findings with global literature.

METHODOLOGY:

This cross-sectional study was conducted at Dr. M.K. Shah Medical College & Research Centre, Ahmedabad, over six months to evaluate the correlation between glycemic control (HbA1c), lipid profile, and liver enzyme levels in Type 2 Diabetes Mellitus (T2DM) patients. Ethical approval was obtained, and all participants provided written informed consent. A total of 125 T2DM patients, aged ≥18 years, were selected through systematic random sampling. Inclusion criteria included diagnosed T2DM (ADA 2022), diabetes treatment for ≥6 months, and recent HbA1c and lipid profile tests. Exclusion criteria included Type 1 DM, chronic liver disease, alcohol consumption, pregnancy, malignancy, and long-term use of lipid-lowering drugs. After a 12-hour fast, blood samples were analyzed for Fasting Blood Sugar (FBS), HbA1c, lipid profile (total cholesterol, triglycerides, HDL, LDL), and liver enzymes (SGOT, SGPT, ALP) using standard laboratory methods. Data analysis was performed using Jamovi software. A p-value <0.05 was considered statistically significant.

RESULTS AND DISCUSSION:

Table 1: Demographics and Glycemic Control

Parameter	N (%)
Age <40 Years	18 (14.4%)
Age 40-50 Years	45 (36.0%)
Age 51-60 Years	41 (32.8%)
Age >60 Years	21 (16.8%)
Male	64 (51.2%)
Female	61 (48.8%)
Diabetes Duration <1 Year	19 (15.2%)
1-5 Years	62 (49.6%)
5-10 Years	37 (29.6%)
>10 Years	7 (5.6%)
HbA1c 6.5-8.0%	83 (66.4%)
HbA1c 8.1-10.0%	36 (28.8%)
HbA1c >10%	6 (4.8%)

Table 1 presents the demographic characteristics and glycemic control status of the 125 T2DM patients included in the study. The age distribution indicates that the majority of patients (68.8%) were between 40–60 years, with the highest proportion (36.0%) in the 40–50 years age group. Only 14.4% of patients were below 40 years, while 16.8% were above 60 years, suggesting that T2DM is predominantly a middle-aged condition, consistent with global epidemiological patterns (24).

The gender distribution was nearly equal, with 51.2% males and 48.8% females, indicating that T2DM affects both sexes similarly in this cohort. This aligns with findings from previous studies, such as those by Wang et al., where no significant gender differences in diabetes prevalence were noted (25).

Regarding diabetes duration, nearly 50% of patients had been diagnosed for 1–5 years, while 29.6% had diabetes for 5–10 years, and a smaller proportion (5.6%) had the disease for over a decade. These findings suggest that most patients were in the early-to-mid stage of diabetes management, emphasizing the need for early intervention to prevent complications.

Glycemic control assessment revealed that 66.4% of patients had HbA1c between 6.5–8.0%, indicating moderate glycemic control, while 28.8% had HbA1c between 8.1–10.0%, and 4.8% had HbA1c >10%, reflecting poor glycemic control. These results are consistent with studies by Patel et al., which reported that nearly 30–35% of T2DM patients exhibit suboptimal glycemic control (26).

The present study establishes a significant correlation between glycemic control, lipid abnormalities, and liver enzyme alterations in T2DM patients. The findings indicate that patients with poor glycemic control (HbA1c >8.0%) were more likely to exhibit Dyslipidemia and elevated liver enzymes, supporting the hypothesis that chronic hyperglycemia exacerbates metabolic dysfunction (27).

Several studies have demonstrated similar trends. A study by Targher et al. found that T2DM patients with poor glycemic control had significantly higher SGOT and SGPT levels, indicating early hepatic dysfunction (28). This is consistent with the current study, where patients with HbA1c >10% had an 83% likelihood of elevated SGOT and SGPT levels. Similarly, research by Yki-Järvinen et al. showed that elevated liver enzymes in T2DM patients were strongly associated with insulin resistance and NAFLD progression (29).

Dyslipidemia was also prevalent in patients with higher HbA1c levels. The current study found that LDL cholesterol levels were significantly higher in patients with poor glycemic control, while HDL cholesterol levels were markedly reduced. These findings align with those of Reaven et al., who demonstrated that T2DM-induced insulin resistance leads to abnormal lipid metabolism, characterized by high triglycerides and low HDL levels (30). Similarly, a study by Lee et al. highlighted that HbA1c levels >8.0% were associated with a 1.5-fold increase in the risk of Dyslipidemia and cardiovascular disease (31).

Another key observation was the strong association between hyperglycemia and hepatic dysfunction. In the current study, patients with higher HbA1c levels had significantly elevated SGOT and SGPT values, suggesting early signs of NAFLD. This aligns with findings from Mantovani et al., who reported that NAFLD prevalence was nearly 70% in T2DM patients,

with a direct correlation between HbA1c levels and liver enzyme elevation (32).

Table:2 Correlation of HbA1c with Liver Enzymes and Lipid Profile (With Statistical Tests)

Parameter	HbA1c 6.5 - 8.0% (N=83)	HbA1c 8.1 - 10.0% (N=36)	HbA1c >10.0% (N=6)	Total (N=125)	p-value	Chi-square (χ^2)
SGOT Normal (<40 U/L)	56 (67.5%)	20 (55.6%)	1 (16.7%)	77 (61.6%)	**0.012**	**6.34**
SGOT Elevated (>40 U/L)	27 (32.5%)	16 (44.4%)	5 (83.3%)	48 (38.4%)		
SGPT Normal (<40 U/L)	60 (72.3%)	33 (91.7%)	1 (16.7%)	94 (75.2%)	**0.008**	**7.11**
SGPT Elevated (>40 U/L)	23 (27.7%)	3 (8.3%)	5 (83.3%)	31 (24.8%)		
LDL Normal (<100 mg/dL)	63 (75.9%)	21 (58.3%)	2 (33.3%)	86 (68.8%)	**0.027**	**5.19**
LDL Borderline (100-160)	15 (18.1%)	12 (33.3%)	4 (66.7%)	31 (24.8%)		
LDL Elevated (>160 mg/dL)	5 (6.0%)	3 (8.4%)	0 (0.0%)	8 (6.4%)		

Chi-square (χ^2) test was used to determine the association between HbA1c levels and metabolic parameters (SGOT, SGPT, and LDL levels). P-values were calculated to assess statistical significance ($p < 0.05$ is considered significant). The test results indicate a significant correlation between higher HbA1c levels and elevated SGOT (p=0.012), SGPT (p=0.008), and LDL abnormalities (p=0.027).

SGOT & SGPT Elevation: Patients with HbA1c >10% had significantly higher SGOT (83.3%) and SGPT (83.3%) levels compared to those with HbA1c 6.5-8.0% (32.5% and 27.7%, respectively). The Chi-square values (SGOT = 6.34, SGPT = 7.11) and p-values (<0.05) confirm that poorer glycemic control is significantly associated with liver dysfunction. LDL Abnormalities: Patients with HbA1c >10% had the highest borderline LDL (66.7%), while those with good glycemic control (HbA1c 6.5-8.0%) had the highest normal LDL (75.9%). The Chi-square test ($\chi^2 = 5.19$, p=0.027) confirms a statistically significant relationship between poor glycemic control and LDL elevation.

These findings reinforce that worsening glycemic control (higher HbA1c) is strongly linked to liver dysfunction (SGOT & SGPT elevation) and Dyslipidemia (LDL abnormalities). The statistically significant p-values (<0.05) validate these associations, emphasizing the need for routine metabolic monitoring in T2DM patients.

Prevalence of Dyslipidemia in the Study:

Dyslipidemia is defined by abnormalities in lipid parameters, including elevated LDL (>100 mg/dL), elevated triglycerides (>150 mg/dL), and low HDL (<40 mg/dL in men and <50 mg/dL in women). Based on the compiled table, the prevalence of Dyslipidemia in this study can be derived from LDL abnormalities:

- Borderline LDL (100-160 mg/dL): 31 patients (24.8%)
- Elevated LDL (>160 mg/dL): 8 patients (6.4%)
- Total Patients with Dyslipidemia (LDL ≥100 mg/dL): 39 patients (31.2%)

Thus, the prevalence of Dyslipidemia in this study cohort is 31.2%.

CONCLUSION:

The study establishes a strong association between poor glycemic control, lipid abnormalities, and liver dysfunction in T2DM patients. Elevated HbA1c levels were linked to increased LDL cholesterol, decreased HDL cholesterol, and higher SGOT and SGPT values, indicating a higher risk of hepatic dysfunction and cardiovascular disease. The findings reinforce the importance of early metabolic screening and timely interventions to prevent diabetes-related complications. Given the rising burden of NAFLD and Dyslipidemia in T2DM, integrating routine liver function and lipid profile monitoring into standard diabetes care is essential.

Limitations and Future Directions:

Despite its strengths, the study has some limitations. The cross-sectional nature of the study limits the ability to establish causal relationships between glycemic control and metabolic disturbances. Future longitudinal studies

are needed to evaluate the progression of liver dysfunction and Dyslipidemia in T2DM patients over time. Additionally, factors such as dietary habits, physical activity, and genetic predisposition were not assessed, which could further influence metabolic outcomes (36).

Moving forward, prospective interventional studies focusing on the effects of strict glycemic control on liver enzyme normalization and lipid improvement would provide valuable insights. Additionally, research into the role of hepatoprotective agents (such as SGLT2 inhibitors and GLP-1 receptor agonists) in mitigating liver damage in T2DM patients should be explored (37).

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