REVIEW ARTICLE

Liver Function Test and Diabetes Mellitus: Correlation from a Laboratory Perspective

Aditya Chilay[1], Neha Mehra[2], Moumita Misra[3], Raj Jatale[4], Shibani Ramchandran[5]

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Abstract

Aims and objectives: To study the correlation of LFTs with DM in the Indian population.

Background: Diabetes mellitus (DM) is a metabolic disorder characterized by increased blood glucose levels, resulting from defects in insulin secretion, insulin action, or both. Glucose is an important regulator of various pancreatic β-cell processes, including insulin biosynthesis and release. The liver plays an important role in glucose homeostasis. Evidence of deranged liver functions is observed in long-standing DM and a slight elevation of liver enzymes is seen in insulin resistance. Insulin resistance results in the production of free fatty acids which damage the liver parenchyma and result in elevation of the liver enzymes, such as alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), and gammaglutamyltranspeptidase (GGTP) in the serum.

Materials and methods: A retrospective analysis of 46,344 cases over a span of 3 years (2020–2022) was conducted in a referral laboratory in Mumbai. The patients included those who had tested for liver function tests (LFTs) [including SGPT, SGOT, ALP, GGTP, lactate dehydrogenase (LDH)], blood sugar (fasting and post lunch), and HbA1c.

Results: Overall 32.11% of the study population was diabetic. Among patients who had done glucose fasting, glucose postprandial, and HbA1c, 17.61% of patients were found to be diabetic at fasting, 15.76% at postprandial and 32.59% had elevated HbA1c levels. Maximum abnormality in LFT was observed in direct bilirubin (18.76%). Multiple logistic regression determined that abnormal ALP [odds ratio (OR): 1.4267, $p < 0.0001$], abnormal GGTP (OR: 1.87, $p < 0.0001$), and abnormal SGPT (ALT) (OR: 1.33, $p < 0.0001$) were independent associates with diabetes.

Conclusion: Long-standing or chronic diabetes due to its multisystem affection can adversely affect liver functions. Regulator monitoring of LFTs is essential in diabetic patients to avoid long-term complications.

Keywords: Alanine aminotransferase, Alkaline phosphatase, Aspartate aminotransferase, Gammaglutamyltranspeptidase, Liver function tests, Type 2 diabetes mellitus.

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Introduction

Diabetes mellitus (DM) refers to a group of metabolic disorders characterized by hyperglycemia along with disorders in carbohydrate, lipid, and protein metabolism due to defects in insulin secretion, insulin action, or both.[1] Most patients with diabetes are prone to increased risk of nephropathy, neuropathy, retinopathy, heart disease, and stroke; however, the risk of having liver disorder cannot be completely ruled out. The liver, due to its ability to store glycogen and synthesize glucose from non-carbohydrate sources, plays a central and critical role in the regulation of carbohydrate metabolism and maintaining glucose homeostasis. Due to this, the liver is more sensitive to diseases in subjects with metabolic diseases like DM.[2] In hyperglycemia, intracellular glycogen accumulates in hepatocytes in response to increased glycogen synthesis. This causes liver injury where there is a mild increase in aminotransferase.[3] The spectrum of liver disorders in diabetes includes fatty liver diseases, cirrhosis, liver carcinoma, and liver failure.[4] Liver enzymes like SGPT, SGOT, and gammaglutamyltranspeptidase (GGTP) are elevated in patients with DM and are a good predictor of the prognosis of the disease.[5,6] Many studies have proven to have a positive association between diabetes and elevated liver enzymes. So it is important to monitor liver function tests (LFTs) on a regular basis in diabetic patients.[7]

[1–5]Metropolis Healthcare LTD, Mumbai, Maharashtra, India

Corresponding Author: Aditya Chilay, Metropolis Healthcare LTD, Mumbai, Maharashtra, India, Phone: +91 9920290168, e-mail: aditya.chilay@metropolisindia.com

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Materials and Methods

A retrospective study of 46,344 cases was conducted in the Mumbai Region over a period of 3 years from 2020 to 2022. Serum samples were used to estimate LFTs and blood sugar levels. EDTA (plasma) samples were used to estimate HbA1c levels. Liver function test, blood sugar fasting and post-lunch were measured on a Cobas analyzer. HbA1c was estimated on Tosoh and Bio-rad analyzers.

Table 1: Age and gender-wise distribution

	Frequency	*Percentage*
Age-group		
18–30	2,322	5.01%
31–45	11,915	25.71%
46–60	14,640	31.59%
>60	17,467	37.69%
Gender		
Female	18,523	39.97%
Male	27,821	60.03%

Inclusion Criteria

- Patients who had tested for fasting blood glucose levels and LFTs
- Patients who had tested for postprandial blood glucose levels and LFTs
- Patients who had tested for HbA1c levels and LFTs

Exclusion Criteria

- Patients who had undergone diabetes tests but not LFTs were excluded from the study.

Statistical Analysis Method

MS Excel was used for data recording. Continuous variables are reported as mean ± standard deviation (SD), median [interquartile range (IQR)] and range. Discrete variables are summarized in terms of frequencies and percentages.

Person's correlation coefficient was used to analyze relation between diabetes parameters (glucose fasting, glucose postprandial, HbA1c) with liver function parameters (alkaline phosphatase (ALP), bilirubin-direct, bilirubin-indirect, bilirubin-total, GGTP, lactate dehydrogenase (LDH), SGOT [aspartate aminotransferase (AST)] and SGPT [alanine aminotransferase (ALT)]. For the association between the diabetic group and the control group with LFT Chi-square test was used.

To determine an independent association of liver function parameters with diabetes, a multiple binary logistic regression using stepwise regression analysis was performed. The stepwise regression builds the model by adding or removing variables based on their statistical significance. Variables that were not statistically significant ($p > 0.05$) have been removed from the final regression model. In the regression model, dependent variables were classified as diabetics group: 1 and control group: 0 and results were reported as odds ratio (OR) and *p*-values.

The statistical analysis was performed using "R Studio version 1.4.1103." A two-tailed *p*-value of < 0.05 was considered to be statistically significant.

Results

A total of 46,344 cases were studied from 2020 to 2022 of which 60.03% were male and 39.97% were females age-group distribution showed that the majority of the patients were older than 60 years of age followed by 46–60 years (Table 1).

Among patients who were tested for LFTs, direct bilirubin levels showed the highest percentage of abnormality (18.76%), followed by LDH (13.08%) levels (Table 2).

Among the total patients tested for glucose fasting, glucose postprandial, and HbA1c, 17.61% patients were found to be diabetic

Table 2: Distribution of LFTs

Liver tests	*Frequency*	*Percentage*
ALP		
Abnormal	3,926	8.47%
Normal	42,418	91.53%
Bilirubin-direct		
Abnormal	8,693	18.76%
Normal	37,651	81.24%
Bilirubin-indirect		
Abnormal	801	1.73%
Normal	45,543	98.27%
Bilirubin-total		
Abnormal	1,928	4.16%
Normal	44,416	95.84%
GGTP		
Abnormal	4,006	8.64%
Normal	42,338	91.36%
LDH		
Abnormal	6,060	13.08%
Normal	40,284	86.92%
SGOT (AST)		
Abnormal	2,992	6.46%
Normal	43,352	93.54%
SGPT (ALT)		
Abnormal	2,731	5.89%
Normal	43,613	94.11%

Table 3A: Overall distribution of diabetic cases

Diabetes tests	*Frequency*	*Percentage*
Glucose fasting		
Normal	27,732	59.84%
Impaired fasting	10,452	22.55%
Elevated levels	8,160	17.61%
Glucose postprandial		
Normal	15,576	64.88%
Impaired tolerance	4,647	19.36%
Elevated levels	3,784	15.76%
HbA1c		
Nondiabetic	11,251	24.28%
Prediabetic	19,990	43.13%
Elevated levels	15,103	32.59%

at fasting, 15.76% showed high postprandial levels, and 32.59% had elevated HbA1c levels (Table 3A).

Further, the patients were divided into two groups diabetic group and a control group. Patients showing elevated levels of any one parameter; glucose fasting, glucose postprandial, or HbA1c elevated were considered diabetic. Based on this 34.11% of patients were diabetic (Table 3B).

Positive correlation of glucose fasting was observed with ALP ($r = 0.1206$, $p < 0.0001$) and GGTP ($r = 0.1178$, $p < 0.0001$) (Table 4).

Postprandial blood glucose also showed a positive correlation with ALP ($r = 0.1138$, $p < 0.0001$) and GGTP ($r = 0.1502$, $p < 0.0001$) (Table 5).

Table 3B: Comparison of diabetics vs nondiabetics

Diabetes	*Frequency*	*Percentage*
Diabetic group	15,807	34.11%
Control group (nondiabetics)	30,537	65.89%

Table 4: Correlation of fasting glucose with abnormal LFTs

Liver test	*Correlation coefficient (r) (96% CI)*	*p-value*
ALP	0.1206 (from 0.1116 to 0.1296)	<0.0001
Bilirubin-direct	0.01094 (from 0.001835 to 0.02004)	0.0185
Bilirubin-indirect	−0.02591 (from −0.03501 to −0.01681)	<0.0001
Bilirubin-total	−0.007541 (from −0.01664 to 0.001563)	0.1045 0.005742
GGTP	0.1176 (from 0.1086 to 0.1266)	<0.0001
LDH	0.005742 (from −0.003363 to 0.01485)	0.2164
SGOT (AST)	0.04346 (from 0.03437 to 0.052)	<0.0001
SGPT (ALT)	0.07560 (from 0.06655 to 0.08465)	<0.0001

Table 5: Correlation of postprandial blood glucose with abnormal LFTs

Liver test	*Correlation coefficient (r) (96% CI)*	*p-value*
ALP	0.1138 (from 0.1013 to 0.1263)	<0.0001
Bilirubin-direct	0.004309 (from −0.008341 to 0.01696)	0.5043
Bilirubin-indirect	−0.05717 (from −0.06977 to −0.04455)	<0.0001
Bilirubin-total	−0.03234 (from −0.04497 to −0.01970)	<0.0001
GGTP	0.1502 (from 0.1378 to 0.1626)	<0.0001
LDH	0.02886 (from 0.01621 to 0.04149)	<0.0001
SGOT (AST)	0.03376 (from 0.02112 to 0.04639)	<0.0001
SGPT (ALT)	0.06944 (from 0.05684 to 0.08202)	<0.0001

HbA1c value showed a positive correlation with ALP ($r = 0.1083$, $p < 0.0001$), and GGTP (0.1019, $p < 0.0001$) while a negative correlation with bilirubin-indirect ($r = -0.1199$, $p < 0.0001$) and bilirubin-total ($r = -0.09158$, $p < 0.0001$) (Table 6).

Table 7 shows the association of LFT in the diabetic group vs the control group. It was observed that except bilirubin-direct ($p = 0.0747$) all other LFT parameters showed statistically significant association with blood glucose and HbA1c levels.

Based on the statistically significant variables (Table 8), a multiple binary logistic regression using stepwise regression analysis was performed to determine the independent association of liver function parameters with diabetes. It was observed that

Table 6: Correlation of HbA1c with abnormal LFTs

Liver test	*Correlation coefficient (r) (96% CI)*	*p-value*
ALP	0.1083 (from 0.09934 to 0.1173)	<0.0001
Bilirubin-direct	−0.03913 (from −0.04822 to −0.03004)	<0.0001
Bilirubin-indirect	−0.1199 (from −0.1289 to −0.1110)	<0.0001
Bilirubin-total	−0.09158 (from −0.1006 to −0.08254)	<0.0001
GGTP	0.1019 (from 0.09285 to 0.1109)	<0.0001
LDH	0.01654 (from 0.007440 to 0.02564)	0.0004
SGOT (AST)	0.01817 (from 0.009064 to 0.02727)	0.0001
SGPT (ALT)	0.04763 (from 0.03855 to 0.05671)	0.04763

abnormal ALP (OR: 1.4267, $p < 0.0001$), abnormal GGTP (OR: 1.87, $p < 0.0001$), and abnormal SGPT (ALT) (OR: 1.33, $p < 0.0001$) had an independent association with diabetic.

Discussion

Diabetes mellitus being a metabolic disorder, leads to multisystem affection. Apart from microvasculature and macrovasculature involvement that occurs due to elevated blood glucose levels, diabetics are also seen to have compromised immune function. The liver plays an important role in carbohydrate metabolism. In type 2 DM (T2DM), the loss of the direct effect of insulin on the hepatic functions may lead to increased hepatic glucose production. India is at the epicenter of the diabetes epidemic, the diabetes cases are estimated to reach 80 million by 2030. In the current study, out of the total 46344 cases tested, 34.11% of patients were diabetic. In this study, a comparison of ALP levels with fasting, and postprandial glucose showed a positive correlation with respect to each. In patients with high HbA1c levels also, the ALP levels were high. Alkaline phosphatase thus, showed a positive correlation with diabetes. Siddiqa et al. also reported similar findings.[8] In their study, the percentage of deranged LFTs was 39.20%. SGPT was elevated in 19.60% of patients and ALP was elevated in 14.70% of diabetic patients. Mandal et al. also reported similar findings.[9] Bora et al. in their study on LFT dysfunction in type 2 diabetes patients reported that 71.25% of patients had abnormal LFTs.[10] This was seen in some other previous studies as well. It has also been seen that T2DM is associated with abnormal hepatocellular functions. Similarly, abnormal liver enzymes in diabetes have also been associated with underlying hepatitis C infections and non-alcoholic fatty liver diseases (NAFLDs). Kocabay et al. reported that ALP is a good predictor and early diagnostic tool for non-alcoholic steatohepatitis as it helps in assessing the degree of fibrosis.[10] Whenever there is liver injury, as in cases of NAFLDs, or in cases of insulin resistance, due to fat deposition, SGPT and GGTP levels increase.[9,11] Thus these markers can be used to predict diabetes and the extent of liver damage, which can happen with advancing diabetes stage. DM is the most common metabolic disorder worldwide. The prognosis of diabetes is inversely associated with the complications which may occur in the course of illness. Hepatic fat accumulation is the most

Table 7: Comparison of LFT parameters in diabetic patients and nondiabetic patients

	Diabetes				
	Diabetic group		*Control group*		
	Frequency	*Percentage*	*Frequency*	*Percentage*	*p-value*
ALP					
Abnormal	1,717	10.86%	2,209	7.23%	<0.0001
Normal	14,090	89.14%	28,328	92.77%	
Bilirubin-direct					
Abnormal	2,894	18.31%	5,799	18.99%	0.0747
Normal	12,913	81.69%	24,738	81.01%	
Bilirubin-indirect					
Abnormal	186	1.18%	615	2.01%	0.0001
Normal	15,621	98.802%	29,922	97.99%	
Bilirubin-total					
Abnormal	495	3.13%	1,433	4.69%	0.0001
Normal	15,312	96.87%	29,104	95.31%	
GGTP					
Abnormal	2,013	12.73%	1,993	6.53%	0.0001
Normal	13,794	87.27%	28,544	93.47%	
LDH					
Abnormal	2,173	13.75%	3,887	12.73%	0.0021
Normal	13,634	86.25%	26,650	87.27%	
SGOT (AST)					
Abnormal	1,350	8.54%	1,642	5.38%	0.0001
Normal	14,457	91.46%	28,895	94.62%	
SGPT (ALT)					
Abnormal	1,260	7.97%	1,471	4.82%	0.0001
Normal	14,547	92.03%	29,066	95.18%	

Table 8: Multiple logistic regression analysis

		Multiple logistic regression		
Parameters	*Variable*	*p-value*	*OR*	*95% CI OR*
ALP	Normal	Ref	1	–
	Abnormal	<0.0001	1.4265	from 1.3336 to 1.5258
Bilirubin-total	Normal	Ref	1	–
	Abnormal	<0.0001	0.6267	from 0.5640 to 0.6964
GGTP	Normal	Ref	1	–
	Abnormal	<0.0001	1.8771	from 1.7513 to 2.0119
SGPT (ALT)	Normal	Ref	1	–
	Abnormal	<0.0001	1.3392	from 1.2320 to 1.4558

commonly seen complication and it affects 40–70% of patients.[12] Unfortunately, obesity also acts as a confounding variable, thereby worsening the prognosis. Fat is stored in the liver in the form of triglycerides (TG), mainly due to increased fat transport to the liver, enhanced hepatic fat synthesis, decreased oxidation or removal of fat from the liver. Steatosis progresses from micro to macro vesicular, thereby impairing liver function, ultimately resulting in fibrosis and cirrhosis.[13] Central obesity is one of the strongest risk factors in the development of NAFLD.[14]

In patients with long-standing diabetes, abnormalities in LFTs can be due to multiple factors. Hyperinsulinemia might directly lead to hepatic insulin resistance which in turn may lead to fatty changes. The fat accumulation in the liver maybe toxic to hepatocytes, leading to an increase in transaminases and diminished synthetic capacity of the liver.[13] The insulin-resistant state is also characterized by an increase in pro-inflammatory cytokines such as tumor necrosis factor (TNF), which further contributes to hepatocellular injury.[14] NAFLD is an important hepatic manifestation of DM and more specifically SGPT has been used as a marker of NAFLD as seen in various studies.[15]

In the current study, it was also observed that apart from ALP levels, GGTP, SGOT, and SGPT were also significantly elevated ($p < 0.0001$), as compared to the control group (nondiabetics). In multiple regression analysis, we concluded that ALP, GGTP, and SGPT had OR more than 1 ($p < 0.0001$). Wang et al. in their study concluded that elevated ALP along with GGTP levels can be associated with diabetes incidence. The study further concluded that ALT and GGTP can be good predictors of high-risk T2DM.[9] Jha et al. in their study on the Bangladeshi population observed that SGPT was elevated in 17% and ALP was elevated in 13% of cases.[16] The regression analysis performed further showed that GGTP has an independent association with the prevalence of T2DM. Shibabaw et al. in their study on the North Ethiopian population also observed elevated SGPT and SGOT in diabetic patients.[17] Another reason observed for such alterations in the liver enzymes is the glycation and resultant oxidative stress in tissues, that occurs as a complication of chronic diabetes. This oxidative stress and cytokine production results in altered liver enzymes due to hepatocellular dysfunctions.[18] Dundi et al. from their study on the rural Indian population concluded that liver dysfunction in diabetics worsens with advancing diabetes, hence assessment of liver function should also be part of diabetes complication management.[19] Some studies also showed a gender-wise variation in liver enzyme levels. Noroozi et al. reported that elevation in

SGPT, SGOT, and GGTP were associated with age and gender.[20] Bora et al. also reported that the most common elevated enzyme in males was ALP and in females is SGPT.[1] In the current study, however, we did not find any variability in elevated liver enzymes due to gender.

Salmela et al. studied the LFTs in diabetic patients, where 57% were found to have at least one abnormal LFT parameter and 27% had at least two abnormal LFT parameters.[21] Balogun et al. observed a high prevalence of deranged LFTs of between 71.2 and 70%, respectively among the diabetic population.[22] In a study by Wang et al., it was found that, increased ALT and GGTP were significantly associated with an increased risk of T2DM.[9,23] Similar to our study, in regression analysis they found out that for SGPT and GGTP, OR was more than 1 (2.00 and 2.38), respectively. However, for SGOT, ALP, and LDH, the null association was observed.

Conclusion

It can be concluded from the study that SGPT, GGTP, ALP, and SGOT were significantly elevated in patients with diabetes as compared to the healthy nondiabetic population. Multiple regression analyses of blood glucose and liver functions showed significant differences with respect to SGPT, ALP, and GGTP. Diabetes being a microvascular condition, hepatocellular damage may occur as the disease advances. Hence in diabetic patients, periodic evaluation of LFTs is essential to avoid long-term complications in the future. Thus, apart from other important tests, LFTs when included as part of diabetes complication assessment can help assess the degree of liver dysfunctions due to T2DM.

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