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Original Article

Changes in Plasma Lipid Profile as a Potential Predictor of Dengue Severity

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ABSTRACT

Background: *This study aimed to investigate changes in plasma lipid profile as potential predictors of disease severity in dengue infection.* ***Methods & Materials:*** *A prospective observational study was conducted on 120 laboratory-confirmed dengue patients, classified according to the WHO 2009 criteria as dengue without warning signs (n=52), dengue with warning signs (n=46), and severe dengue (n=22). Plasma lipid profile including total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglycerides during admission. Clinical and laboratory parameters were recorded, and their correlation with lipid levels were analyzed.* ***Results:*** *Significantly lower levels of total cholesterol, HDL, and LDL were observed in patients with severe dengue compared to those with milder forms (p<0.001), and in non-survivors (n=6) compared to survivors (n=114) (p<0.001). ROC curve analysis revealed good discriminatory power of total cholesterol (AUC=0.842), HDL (AUC=0.826), and LDL (AUC=0.834) for predicting severe dengue. Cut-off values of total cholesterol ≤3.10 mmol/L, HDL ≤0.75 mmol/L, and LDL ≤1.80 mmol/L demonstrated optimal sensitivity and specificity. Multivariate analysis confirmed these parameters as independent predictors of severe dengue after adjusting for confounders. Significant negative correlations were observed between lipid levels and markers of disease severity, including thrombocytopenia, elevated liver enzymes, and clinical complications.* ***Conclusions:*** *Changes in plasma lipid profile, particularly decreased total cholesterol, HDL, and LDL levels, are significantly associated with severe dengue and adverse clinical outcomes. These parameters show promise as early predictors of disease progression and could be incorporated into existing risk stratification tools to improve the management of dengue patients.*

Keywords: *Dengue; Severe dengue; Lipid profile; Cholesterol; HDL; LDL; Biomarker; Disease severity; Predictors*

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INTRODUCTION

Dengue virus infection represents one of the most significant mosquito-borne viral diseases globally, with an estimated 390 million infections occurring annually worldwide. [1] The clinical manifestations of dengue infection range from asymptomatic or mild febrile illness to severe forms including dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS), which are characterized by increased vascular permeability, plasma leakage, and hemorrhagic manifestations. [2] Early identification of patients at risk of developing severe dengue is crucial for timely intervention and appropriate management, yet remains challenging due to the dynamic nature of the disease.[3] In recent years, increasing evidence suggests that changes in plasma lipid profiles may serve as potential biomarkers for predicting the severity of dengue infection. [4] Dengue virus is known to modulate host cell lipid metabolism to promote efficient viral replication.[5] Several studies have demonstrated significant alterations in lipid parameters, particularly total cholesterol, low-density lipoprotein (LDL), and high-density lipoprotein (HDL) levels, in patients with dengue infection. [6,7] Van Gorp et al. reported that levels of total plasma cholesterol, HDL, and LDL were significantly decreased in patients with the severest forms of dengue compared to those with mild dengue and healthy controls, suggesting that these parameters could be used as potential predictors of clinical outcome. [8] Biswas et al. further confirmed that lower total serum cholesterol and LDL-C levels at presentation were associated with subsequent risk of developing DHF/DSS, indicating that reduction in LDL-C is likely driving the decreases observed in total serum

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cholesterol levels among dengue patients. [9] These findings suggest that cholesterol blood levels are important correlates of dengue pathophysiology and could be valuable components of a prognostic biomarker panel for predicting severe dengue outcomes. [10] The interplay between lipid metabolism and dengue pathogenesis involves complex mechanisms. The alteration in cholesterol levels has been observed to decrease over the course of illness and differs across disease outcomes, regardless of classification schemes. [11] A potential explanation for these lipoprotein changes may be related to the bidirectional interaction between cytokines and lipoproteins. While lipids are involved in regulating cytokine levels and modifying host immune responses, cytokines like TNF-α and IL-1 can decrease serum cholesterol levels, possibly by influencing the enzyme hydroxymethylglutaryl (HMG) coenzyme A (CoA) reductase. [12] Despite these promising observations, data on the predictive value of plasma lipid profile changes for dengue severity remain limited and somewhat inconsistent. [13] Therefore, this study aims to investigate the association between plasma lipid profile alterations and the severity of dengue infection in 120 patients, to evaluate their potential as early predictors of disease progression and clinical outcomes.

MATERIALS & METHODS

Study Design and Patient Population

This prospective observational study was conducted at our tertiary care hospital from August 2024 to January 2025. A total of 120 patients with laboratory-confirmed dengue infection were enrolled. The clinical diagnosis of dengue was confirmed by serological assays, either by positive IgM response or a four-fold increase in IgG titers. Patients were classified according to the World Health Organization (WHO) 2009 classification criteria into three groups: dengue without warning signs (DWWS), dengue with warning signs (DWS), and severe dengue (SD). The study protocol was approved by the institutional ethics committee, and written informed consent was obtained from all participants or their legal guardians.

Inclusion and exclusion Criteria:

All febrile patient who tests positive for dengue via the NS1 antigen or dengue IgM were included and patients less than 18 years of age, obesity, dyslipidemia patient receiving statin, hypothyroidism, patient taking steroid, oral contraceptive pill were excluded.

Sample Collection and Laboratory Investigations

Blood samples were collected from all patients at the time of admission. All blood samples were immediately immersed in melting ice and subsequently centrifuged at 4°C for 20 minutes at 1600g. Plasma samples were stored at -70°C until assayed. Complete blood count, liver function tests, renal function tests, and coagulation profile were performed as part of routine clinical care.

Lipid Profile Analysis

Plasma levels of cholesterol and triglycerides were determined by enzymatic methods using commercially available reagents (CHOD-PAP reagent; Roche) by means of an automated analyzer. Plasma HDL-cholesterol concentrations were determined after precipitation of LDL, using phosphotingsta-Mg2+. LDL-cholesterol concentrations were calculated according to the Fried Ewald formula. All measurements were performed in duplicate, and the mean values were used for analysis.

Clinical Data Collection

Detailed clinical data including demographic information, medical history, clinical symptoms, examination findings, and laboratory results were recorded using a standardized case report form. Patients were followed up daily during hospitalization to monitor disease progression and clinical outcomes. Severity parameters including capillary leakage (determined by hemoconcentration, pleural effusion, or ascites), bleeding manifestations, organ involvement, and requirement for supportive care were documented.

Statistical Analysis

The plasma levels of the lipid parameters measured are presented as median values with their corresponding interquartile ranges (IQRs) and 95% confidence intervals (CIs). The Mann-Whitney U test was used to compare the respective plasma levels among the different groups. For multiple group comparisons, the Kruskal-Wallis test followed by Dunn's post-hoc test was employed. Correlation between lipid parameters and clinical severity indicators was assessed using Spearman's rank correlation coefficient. To evaluate the predictive value of lipid parameters for severe dengue, receiver operating characteristic (ROC) curve analysis was performed. The area under the ROC curve (AUC), sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated. To examine the effect of cholesterol levels at presentation on subsequent risk of development of severe dengue, relative risks and 95% confidence intervals were calculated using multivariable modified Poisson models, adjusting for potential confounders including age, gender, day of illness at presentation, and secondary infection status.

Multivariate logistic regression analysis was conducted to identify independent lipid parameters associated with severe dengue. Variables with $p<0.1$ in univariate analysis were included in the multivariate model. A p-value <0.05 was considered statistically significant. All statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA) and GraphPad Prism version 9.0 (GraphPad Software, San Diego, CA, USA).

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee (IEC approval number: EMC/ERC/2024/08-1). Patient confidentiality was maintained throughout the study, and data were anonymized for analysis.

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RESULTS

Demographic and Clinical Characteristics

A total of 120 patients with laboratory-confirmed dengue infection were enrolled in the study. The demographic and clinical characteristics of the study population are summarized in Table I. According to the WHO 2009 classification criteria, 52 patients (43.3%) had dengue without warning signs (DWWS), 46 patients (38.3%) had dengue with warning signs (DWS), and 22 patients (18.3%) had severe dengue (SD). The mean age of the study population was 34.7 ± 15.3 years, with a male predominance (62.5%). The majority of cases (73.3%) were secondary dengue infections, as evidenced by serological analysis.

Table – I: Demographic and Clinical Characteristics of Study Population

Characteristic	Total (n=120)	DWWS (n=52)	DWS (n=46)	SD (n=22)	p-value
Age (years), mean ± SD	34.7 ± 15.3	32.8 ± 14.2	35.1 ± 15.8	38.6 ± 16.5	0.276
Gender, n (%)					**0.418**
Male	75 (62.5)	34 (65.4)	30 (65.2)	11 (50.0)	
Female	45 (37.5)	18 (34.6)	16 (34.8)	11 (50.0)	
Duration of fever at admission (days), mean ± SD	4.2 ± 1.8	3.5 ± 1.4	4.5 ± 1.9	5.3 ± 1.7	0.001*
Infection status, n (%)					**<0.001***
Primary	32 (26.7)	24 (46.2)	6 (13.0)	2 (9.1)	
Secondary	88 (73.3)	28 (53.8)	40 (87.0)	20 (90.9)	
Clinical manifestations, n (%)					
Headache	98 (81.7)	40 (76.9)	38 (82.6)	20 (90.9)	0.345
Myalgia	102 (85.0)	42 (80.8)	40 (87.0)	20 (90.9)	0.440
Arthralgia	94 (78.3)	38 (73.1)	38 (82.6)	18 (81.8)	0.462
Retro-orbital pain	68 (56.7)	24 (46.2)	28 (60.9)	16 (72.7)	0.084
Rash	65 (54.2)	26 (50.0)	24 (52.2)	15 (68.2)	0.338
Abdominal pain	62 (51.7)	10 (19.2)	36 (78.3)	16 (72.7)	<0.001*
Vomiting	72 (60.0)	16 (30.8)	36 (78.3)	20 (90.9)	<0.001*
Bleeding manifestations	52 (43.3)	8 (15.4)	26 (56.5)	18 (81.8)	<0.001*
Plasma leakage	44 (36.7)	0 (0.0)	24 (52.2)	20 (90.9)	<0.001*
Organ involvement	24 (20.0)	0 (0.0)	2 (4.3)	22 (100.0)	<0.001*
Length of hospitalization (days), mean ± SD	5.8 ± 2.9	4.2 ± 1.3	6.1 ± 2.2	9.2 ± 3.5	<0.001*
Mortality, n (%)	6 (5.0)	0 (0.0)	0 (0.0)	6 (27.3)	<0.001*

**Statistically significant (p<0.05) DWWS: Dengue without warning signs; DWS: Dengue with warning signs; SD: Severe dengue.*

The plasma lipid profiles of all patients at admission are presented in Table II. Significant differences were observed in the levels of total cholesterol, HDL, and LDL across the three severity groups, with the lowest levels observed in the severe dengue group. No significant difference was found in triglyceride levels among the three groups.

Table – II: Plasma Lipid Profile at Admission According to Disease Severity

Lipid Parameter	DWWS (n=52)	DWS (n=46)	SD (n=22)	p-value
Total cholesterol (mmol/L), median (IQR)	4.28 (3.86-4.72)	3.52 (3.14-3.94)	2.84 (2.46-3.22)	<0.001*
HDL (mmol/L), median (IQR)	1.12 (0.96-1.28)	0.88 (0.76-1.02)	0.66 (0.54-0.78)	<0.001*
LDL (mmol/L), median (IQR)	2.65 (2.34-2.98)	2.06 (1.82-2.34)	1.62 (1.38-1.86)	<0.001*
Triglycerides (mmol/L), median (IQR)	1.74 (1.24-2.38)	1.92 (1.36-2.54)	2.12 (1.48-2.76)	0.216

**Statistically significant (p<0.05) DWWS: Dengue without warning signs; DWS: Dengue with warning signs; SD: Severe dengue; IQR: Interquartile range; HDL: High-density lipoprotein; LDL: Low-density lipoprotein;*

When comparing survivors (n=114) versus non-survivors (n=6), significantly lower levels of total cholesterol, HDL, and LDL were observed in the non-survivor group, as shown in Table III.

Table – III: Comparison of Plasma Lipid Profile Between Survivors and Non-survivors

Lipid Parameter	Survivors (n=114)	Non-survivors (n=6)	p-value
Total cholesterol (mmol/L), median (IQR)	3.76 (3.02-4.38)	2.24 (1.92-2.58)	<0.001*
HDL (mmol/L), median (IQR)	0.94 (0.72-1.16)	0.52 (0.44-0.62)	<0.001*
LDL (mmol/L), median (IQR)	2.28 (1.78-2.78)	1.26 (1.04-1.48)	<0.001*
Triglycerides (mmol/L), median (IQR)	1.88 (1.34-2.52)	2.32 (1.64-2.88)	0.184

**Statistically significant (p<0.05) IQR: Interquartile range; HDL: High-density lipoprotein; LDL: Low-density lipoprotein;*

ISSN: 2663-9491 E-ISSN: 2789-6897

Correlation Between Lipid Parameters and Disease Severity Indicators

Correlation analysis revealed significant negative correlations between total cholesterol, HDL, and LDL levels and various clinical parameters of disease severity, as shown in Table IV.

Table – IV: Correlation Between Lipid Parameters and Disease Severity Indicators

Lipid Parameter	Platelet Count	Hematocrit	ALT	AST	Duration of Fever	Length of Hospital Stay
Total cholesterol	r = 0.436, p<0.001*	r = -0.382, p<0.001*	r = -0.394, p<0.001*	r = -0.408, p<0.001*	r = -0.316, p<0.001*	r = -0.426, p<0.001*
HDL	r = 0.408, p<0.001*	r = -0.346, p<0.001*	r = -0.358, p<0.001*	r = -0.372, p<0.001*	r = -0.285, p=0.002*	r = -0.394, p<0.001*
LDL	r = 0.418, p<0.001*	r = -0.366, p<0.001*	r = -0.376, p<0.001*	r = -0.392, p<0.001*	r = -0.302, p<0.001*	r = -0.412, p<0.001*
Triglycerides	r = -0.184, p=0.044*	r = 0.168, p=0.066	r = 0.196, p=0.032*	r = 0.202, p=0.027*	r = 0.154, p=0.093	r = 0.188, p=0.040*

**Statistically significant (p<0.05) HDL: High-density lipoprotein; LDL: Low-density lipoprotein;; ALT: Alanine aminotransferase; AST: Aspartate aminotransferase; r: Spearman's correlation coefficient*

Predictive Value of Lipid Parameters for Severe Dengue

To evaluate the potential of lipid parameters as early predictors of severe dengue, ROC curve analysis was performed (Table V). Total cholesterol, HDL, and LDL levels at admission demonstrated good discriminatory power for predicting the development of severe dengue.

Table – V: ROC Curve Analysis for Prediction of Severe Dengue Using Lipid Parameters

Lipid Parameter	AUC (95% CI)	Cut-off Value	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Total cholesterol	0.842 (0.766-0.918)	≤3.10 mmol/L	81.8	78.6	46.2	95.1
HDL	0.826 (0.746-0.906)	≤0.75 mmol/L	77.3	75.5	42.5	93.8
LDL	0.834 (0.754-0.914)	≤1.80 mmol/L	77.3	76.5	43.6	93.8
Triglycerides	0.592 (0.472-0.712)	≥2.00 mmol/L	63.6	55.1	25.9	86.1

AUC: Area under the curve; CI: Confidence interval; PPV: Positive predictive value; NPV: Negative predictive value; HDL: High-density lipoprotein; LDL: Low-density lipoprotein;

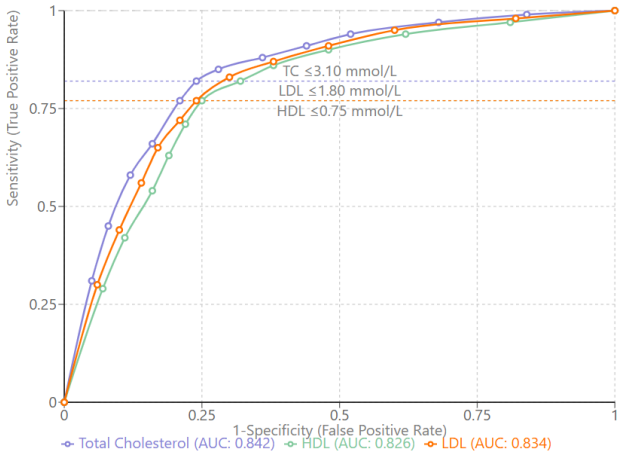

Figure – 1: ROC curves for total cholesterol, HDL, and LDL levels for predicting severe dengue

Multivariate logistic regression analysis was performed to identify independent predictors of severe dengue (Table VI). After adjusting for potential confounders, total cholesterol ≤3.10 mmol/L, HDL ≤0.75 mmol/L, and LDL ≤1.80 mmol/L at admission remained significant independent predictors of severe dengue.

Table – VI: Multivariate Logistic Regression Analysis for Prediction of Severe Dengue

Variable	Adjusted OR (95% CI)	p-value
Age >40 years	1.86 (0.92-3.76)	0.084
Secondary infection	3.42 (1.68-6.97)	0.001*
Platelet count <100,000/mm^3	2.94 (1.46-5.92)	0.003*
ALT >100 U/L	2.58 (1.28-5.18)	0.008*
Total cholesterol ≤3.10 mmol/L	4.26 (1.98-9.16)	<0.001*
HDL ≤0.75 mmol/L	3.68 (1.74-7.78)	<0.001*
LDL ≤1.80 mmol/L	3.92 (1.84-8.36)	<0.001*

**Statistically significant (p<0.05) OR: Odds ratio; CI: Confidence interval; ALT: Alanine aminotransferase; HDL: High-density lipoprotein; LDL: Low-density lipoprotein*

Relationship Between Lipid Parameters and Clinical Complications

The association between lipid parameters at admission and the development of clinical complications during hospitalization is presented in Table VII. Patients who developed plasma leakage, severe bleeding, and organ involvement had significantly lower levels of total cholesterol, HDL, and LDL compared to those without these complications.

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Table – VII: Association Between Lipid Parameters and Clinical Complications

Lipid Parameter	Plasma Leakage		Severe Bleeding		Organ Involvement	
	Present (n=44)	Absent (n=76)	Present (n=28)	Absent (n=92)	Present (n=24)	Absent (n=96)
Total cholesterol (mmol/L), median (IQR)	3.08 (2.65-3.58)*	3.96 (3.36-4.54)	2.92 (2.48-3.36)*	3.88 (3.24-4.46)	2.76 (2.38-3.18)*	3.84 (3.22-4.42)
HDL (mmol/L), median (IQR)	0.78 (0.64-0.94)*	1.02 (0.82-1.22)	0.70 (0.58-0.84)*	0.98 (0.78-1.18)	0.64 (0.52-0.76)*	0.96 (0.78-1.16)
LDL (mmol/L), median (IQR)	1.86 (1.58-2.18)*	2.44 (2.06-2.84)	1.76 (1.50-2.04)*	2.38 (1.98-2.78)	1.62 (1.36-1.88)*	2.34 (1.94-2.76)
Triglycerides (mmol/L), median (IQR)	2.05 (1.48-2.68)	1.82 (1.28-2.42)	2.12 (1.54-2.76)	1.84 (1.30-2.46)	2.18 (1.58-2.82)	1.86 (1.32-2.48)

**Statistically significant (p<0.05) compared to the absence of the complication IQR: Interquartile range; HDL: High-density lipoprotein; LDL: Low-density lipoprotein*

DISCUSSION

This prospective study evaluated the changes in plasma lipid profile as potential predictors of disease severity in 120 patients with dengue infection. Our findings demonstrated that lower levels of total cholesterol, HDL, and LDL at admission were significantly associated with severe dengue manifestations and adverse clinical outcomes, supporting their potential utility as early biomarkers for predicting disease progression. The significant decrease in total cholesterol, HDL, and LDL levels observed in our study aligns with several previous investigations. Van Gorp et al. reported that the plasma lipid profile differs according to the stage of DHF disease severity, with the lowest levels of total cholesterol, HDL, and LDL occurring in patients with the severest disease. [14,15] Similarly, Biswas et al. found that lower total serum cholesterol and LDL-C levels at presentation were associated with subsequent risk of developing DHF/DSS using the WHO 1997 dengue severity classification. [16] Our results corroborate these findings and extend them by demonstrating that the reduction in these lipid parameters correlates not only with disease severity but also with specific clinical complications such as plasma leakage, severe bleeding, and organ involvement. While lipids are involved in regulating cytokine levels and modifying host immune responses, cytokines like TNF-α and IL-1 can decrease serum cholesterol levels, possibly by influencing the enzyme hydroxymethylglutaryl (HMG) coenzyme A (CoA) reductase.[17] The exaggerated inflammatory response in severe dengue, characterized by elevated levels of pro-inflammatory cytokines, might contribute to the more pronounced reduction in cholesterol levels. [18] Another potential mechanism involves the direct interaction between dengue virus and lipoproteins. Soto-Acosta et al. demonstrated that dengue virus infection increases intracellular cholesterol levels at early times post-infection by triggering the modulation of LDL particle uptake and increasing the enzymatic activity of HMG-CoA reductase. [19] This virus-induced alteration in cholesterol metabolism may contribute to efficient viral replication and dissemination. [20] The significant negative correlation between lipid parameters and markers of disease severity, such as elevated liver enzymes and prolonged hospital stay, further supports the relationship between lipid alterations and dengue pathophysiology. Suvarna and Rane reported that the mean cholesterol level was significantly lower in expired patients and those with third-space fluid accumulation, and severe bleeding significantly correlated with cholesterol level and hepatic dysfunction.[21] Our study demonstrated similar correlations, with the lowest cholesterol levels observed in non-survivors. The ROC curve analysis in our study revealed that total cholesterol ≤3.10 mmol/L, HDL ≤0.75 mmol/L, and LDL ≤1.80 mmol/L at admission had good discriminatory power for predicting severe dengue, with AUC values of 0.842, 0.826, and 0.834, respectively. These cut-off values provided relatively high sensitivity and specificity, making them potentially useful as early warning markers. Biswas et al. demonstrated that lower total serum cholesterol and LDL-C levels at presentation were associated with subsequent risk of developing severe dengue outcomes, and thus reduction in LDL-C is likely driving the decreases observed in total serum cholesterol levels among dengue patients.[22] The multivariate analysis confirmed that low total cholesterol, HDL, and LDL levels remained independent predictors of severe dengue after adjusting for potential confounders. This finding is particularly important as it suggests that lipid parameters may add value to existing prediction models for severe dengue. Recent research has suggested that lipid-lowering agents may influence dengue virus infection, as DENV replication is significantly reduced when cholesterol biosynthesis is pharmacologically inhibited. [23] This raises intriguing questions about the potential therapeutic implications of targeting cholesterol metabolism in dengue infection. The association between low lipid levels and clinical complications in our study aligns with previous reports. Although some studies have reported contradictory results regarding the lipid profile in dengue patients, with some describing increased levels of triglycerides, VLDL, and HDL in severe dengue, [24,25,26,] our findings support the predominant evidence that lower cholesterol levels are associated with more severe disease. The discrepancies in previous studies might be attributed to differences in study populations, timing of sample collection, and methods of lipid measurement. Recent studies have shown that PFKFB4, TPM1, PDCL3, and PTPN20A were elevated among patients with severe dengue, and pathway enrichment analysis suggested that insulin pathways and cytoskeleton pathways were involved in the pathophysiology

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of severe dengue. [27,28] These novel biomarkers, along with the lipid parameters evaluated in our study, might enhance the predictive accuracy for severe dengue. Second, pre-infection lipid levels were not available for comparison, making it difficult to distinguish between pre-existing hypocholesterolemia and infection-induced changes. Third, the relatively small sample size of the severe dengue and non-survivor groups might limit the generalizability of our findings. Larger multicenter studies are needed to validate these results. Despite these limitations, our study provides compelling evidence for the potential utility of plasma lipid profile as a predictor of dengue severity. As van Gorp et al. suggested, the plasma lipid profile could be used as a potential predictor for clinical outcome, although the question of whether we can use this in clinical practice has to be answered in future studies. [29, 30] Our study contributes to this growing body of evidence and suggests that monitoring lipid parameters might aid in early identification of patients at risk of developing severe dengue. In our study, demonstrates that lower levels of total cholesterol, HDL, and LDL at admission are significantly associated with severe dengue and adverse clinical outcomes. These parameters show promise as early predictors of disease progression and could be incorporated into existing risk stratification tools to improve the triage and management of dengue patients. Future research should focus on validating these findings in larger cohorts and exploring the underlying mechanisms linking lipid alterations to dengue pathogenesis, which might pave the way for novel therapeutic approaches.

CONCLUSION

Our findings demonstrate that patients with severe dengue consistently exhibit lower lipid levels compared to those with milder forms of the disease, and these alterations are more pronounced in non-survivors than survivors.

Total cholesterol ≤3.10 mmol/L, HDL ≤0.75 mmol/L, and LDL ≤1.80 mmol/L at admission emerged as independent predictors of severe dengue with good sensitivity and specificity. Furthermore, lower lipid levels showed significant correlations with established markers of disease severity, including thrombocytopenia, elevated liver enzymes, and clinical complications such as plasma leakage, severe bleeding, and organ involvement.

These findings suggest that plasma lipid profile could serve as a valuable prognostic marker for identifying patients at risk of developing severe dengue. The measurement of lipid parameters is widely available, relatively inexpensive, and could be easily incorporated into routine clinical assessment. Early identification of high-risk patients would enable timely intervention and appropriate management, potentially reducing morbidity and mortality associated with severe dengue.

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