RESEARCH PAPER

Serum High-Density Lipoprotein Cholesterol Levels and Prognostic Significance in Adult Patients with Sepsis: A Prospective Observational Study

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ABSTRACT

Introduction: Sepsis is a life-threatening organ dysfunction caused by a dysregulated host response to infection. High-density lipoprotein cholesterol (HDL-C), beyond its conventional role in lipid transport, participates in endotoxin binding, inflammatory modulation and endothelial protection. A fall in HDL-C during sepsis may therefore reflect both metabolic stress and the burden of organ dysfunction.

Aim: To assess the relationship between serum HDL-C levels and severity of sepsis using the Sequential Organ Failure Assessment (SOFA) score, and to evaluate the prognostic significance of HDL-C for in-hospital outcome.

Materials and Methods: This hospital-based prospective observational study was conducted in the Department of General Medicine, Adichunchanagiri Hospital and Research Centre, B.G. Nagara, Karnataka, India, from 1 May 2024 to 31 October 2025. A total of 107 adults with sepsis were enrolled. Demographic details, comorbidities, source of infection, SOFA scores on Day 1 and Day 5, serum HDL-C on Day 1 and Day 5, and in-hospital outcome were recorded. HDL-C was estimated by the enzymatic colourimetric cholesterol oxidase-peroxidase method. Statistical analysis was performed using SPSS version 26.0. Shapiro-Wilk test, independent t-test, Chi-square test and Pearson correlation coefficient were applied as appropriate. A p-value <0.05 was considered statistically significant.

Results: Among 107 patients, males constituted 63 (58.9%) and females 44 (41.1%). The commonest age group was 51-60 years (28, 26.2%). Respiratory tract infection was the leading source of sepsis (38, 35.5%). On Day 1, 51 (47.7%) patients had SOFA scores of 6-10, and 27 (25.2%) had SOFA scores >10. Mean HDL-C increased from 34.6±8.9 mg/dL on Day 1 to 39.8±9.4 mg/dL on Day 5. HDL-C showed a significant inverse correlation with SOFA score on Day 1 ($r=-0.61$, $p<0.001$) and Day 5 ($r=-0.66$, $p<0.001$). Survivors had higher mean HDL-C than non-survivors (41.7±7.8 mg/dL vs 28.9±6.5 mg/dL, $p<0.001$). Mortality was 43.1% among patients with HDL-C <40 mg/dL compared with 12.5% among those with HDL-C >=40 mg/dL.

Conclusion: Low serum HDL-C was significantly associated with higher SOFA scores and increased in-hospital mortality among adults with sepsis. Serial HDL-C estimation may serve as a simple adjunct to clinical severity scoring for early prognostic assessment.

Keywords: Biomarkers, Cholesterol, HDL, Prognosis, Sepsis, Sequential Organ Failure Assessment Score

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INTRODUCTION

Sepsis remains one of the most demanding syndromes encountered in acute medicine and critical care. The Sepsis-3 consensus defined it as life-threatening organ dysfunction caused by a dysregulated host response to infection, thereby shifting diagnostic emphasis from inflammation alone to measurable organ injury [1]. Current sepsis management continues to rest on early recognition, timely antimicrobial therapy, haemodynamic optimisation and source control, yet mortality remains substantial, especially when presentation is delayed or organ dysfunction is already established [2].

The global burden is large and uneven. Contemporary estimates suggest that sepsis contributes to millions of deaths every year, with a disproportionate share occurring in low- and middle-income countries [3,4]. In India, tertiary-care intensive care units often receive patients after referral delays, prior antibiotic exposure, advanced comorbidity, or severe community-acquired infection. The Indian Intensive Care Case Mix and Practice Patterns Study has already shown the complexity and resource intensity of critical care delivery across the country [5]. Here, low-cost prognostic markers that can complement clinical judgement have practical relevance, not merely statistical appeal.

The biological course of sepsis is not limited to pathogen invasion. It involves a disturbed interaction between innate immune activation, endothelial injury, microvascular dysfunction, coagulation activation and subsequent immune paralysis [6,7]. These processes also disturb intermediary

metabolism. Lipid and lipoprotein pathways, once viewed largely through a cardiovascular lens, are now recognised as components of host defence during severe infection [8,9].

High-density lipoprotein cholesterol (HDL-C) is of particular interest because HDL particles bind and neutralise pathogen-associated lipid moieties, including lipopolysaccharide and lipoteichoic acid, and facilitate their clearance from the circulation [10]. HDL also has anti-inflammatory, antioxidant, anti-thrombotic and endothelial-protective functions, all of which are biologically relevant to sepsis-related organ dysfunction [9,10]. During sepsis, however, HDL-C levels fall rapidly because of cytokine-driven suppression of apolipoprotein synthesis, compositional remodelling of HDL particles, increased catabolism, and consumption during endotoxin binding [9].

Earlier clinical studies have linked low HDL-C with severe sepsis, prolonged intensive care stay and mortality [11]. Serial organ dysfunction is commonly quantified using the SOFA score, a validated tool that incorporates respiratory, coagulation, hepatic, cardiovascular, neurological and renal domains [12]. The prognostic value of repeated SOFA assessment has also been established in critically ill patients [13]. If HDL-C tracks with SOFA score and outcome, it may offer a routine, inexpensive biochemical signal of disease trajectory.

Evidence from Indian patients remains comparatively limited, despite differences in infection pattern, comorbidity profile, access to critical care and nutritional status. The present study was therefore conducted to assess serum HDL-C levels among adult patients with sepsis and to determine their prognostic significance by examining their relationship with SOFA score and in-hospital outcome.

MATERIALS AND METHODS

Study design and setting: This hospital-based prospective observational study was conducted in the Department of General Medicine, Adichunchanagiri Hospital and Research Centre, B.G. Nagara, Karnataka, India. The study evaluated serum HDL-C levels in adult patients with sepsis and assessed their prognostic significance in relation to organ dysfunction and in-hospital outcome.

Study period: The study was carried out over 18 months, from 1 May 2024 to 31 October 2025.

Study population: Adult patients admitted to the medical wards or intensive care unit during the study period and diagnosed with sepsis were screened for eligibility. Patients aged 18 years and above with suspected or documented infection and an acute increase in SOFA score of at least 2 points were considered eligible. Written informed consent was obtained from the patient or legally acceptable representative before enrolment.

Inclusion criteria: Patients aged 18 years and above, patients fulfilling the operational criteria for sepsis, and patients willing to provide written informed consent or whose legally acceptable representative provided consent were included.

Exclusion criteria: Patients aged less than 18 years, patients with known chronic liver disease, chronic kidney disease on dialysis, malignancy, pregnancy, current lipid-lowering therapy such as statins or fibrates, and patients who died within 24 hours of admission were excluded.

Sample size calculation and sampling method: The sample size was calculated using the single proportion formula $n=Z^2pq/d^2$, where Z was the standard normal deviate at 95% confidence level (1.96), p was the expected proportion based on previous literature, q=1-p, and d was the allowable error. Consecutive eligible patients were recruited during the study period, and 107 patients were included in the final analysis.

Operational definition and severity assessment: Sepsis was operationally defined as suspected or documented infection with an acute increase in SOFA score of >=2 points. SOFA score was calculated on Day 1 and Day 5 using six organ-system domains: respiratory, coagulation, hepatic, cardiovascular, central nervous system and renal. Higher SOFA scores indicated greater organ dysfunction.

Data collection and laboratory assessment: Demographic details, sex, age, comorbidities, presenting illness, source of infection, clinical examination findings and relevant laboratory parameters were recorded. Venous blood samples were collected under aseptic precautions. Serum HDL-C was estimated on Day 1 and repeated on Day 5 by the enzymatic colorimetric cholesterol oxidase-peroxidase method in the central laboratory using standardised and calibrated equipment.

Outcome measures: The primary outcome measure was the association between serum HDL-C levels and sepsis severity assessed by SOFA score. Secondary outcome measures were comparison of HDL-C levels between survivors and non-survivors and the association between HDL-C category and in-hospital mortality.

Follow-up and data completeness: Patients were followed throughout their hospital stay until discharge or death. Day 1 and Day 5 HDL-C and SOFA assessments were available for all 107 patients included in the final analysis.

Table 1. Participant flow of the analysed cohort.

Adult patients with suspected/documented infection assessed during the study period
↓
Eligibility applied using inclusion and exclusion criteria
↓
107 eligible adult patients with sepsis enrolled after written informed consent
↓
Day 1 assessment: clinical profile, SOFA score and serum HDL-C estimation
↓
Day 5 assessment: repeat SOFA score and serum HDL-C estimation
↓
Follow-up until discharge or death; 107 patients included in final analysis

Note: SOFA: Sequential Organ Failure Assessment; HDL-C: high-density lipoprotein cholesterol. The flowchart is created as editable Word text/table content.

Statistical analysis: Data were entered in Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarised as mean±standard deviation. Categorical variables were presented as frequency and percentage. Shapiro-Wilk test was used to assess normality. Independent t-test was used to compare mean HDL-C levels between survivors and non-survivors. Chi-square test was used for categorical associations. Pearson correlation coefficient was used to assess the relationship between HDL-C levels and SOFA score. Two-tailed tests were applied, and p-value <0.05 was considered statistically significant.

Ethical considerations: The study was approved by the Institutional Ethics Committee of Adichunchanagiri Institute of Medical Sciences, B.G. Nagara (IEC No. AIMS/IEC/022/2024, dated 1 April 2024; IEC registration number EC/NEW/INST/2023/KA/0382). Written informed consent was obtained from all participants or their legally acceptable

representatives. Confidentiality of patient information was maintained throughout the study.

RESULTS

A total of 107 adult patients with sepsis were included in the final analysis. The age distribution showed a predominance of middle-aged and elderly patients; the largest age group was 51-60 years (28, 26.2%), followed by 61-70 years (24, 22.4%) and 41-50 years (22, 20.6%). Males constituted 63 (58.9%) patients, while females constituted 44 (41.1%). Hypertension was present in 52 (48.6%), diabetes mellitus in 48 (44.9%), coronary artery disease in 21 (19.6%), and chronic lung disease in 17 (15.9%) patients (Table/Fig 2). The age-distribution chart is shown in Table/Fig 3, and the source-wise infection distribution is shown in Table/Fig 4.

Table 2. Baseline demographic and clinical characteristics of the study population (n=107).

Variable	Number (%)
Age group <=30 years	6 (5.6%)
Age group 31-40 years	12 (11.2%)
Age group 41-50 years	22 (20.6%)
Age group 51-60 years	28 (26.2%)
Age group 61-70 years	24 (22.4%)
Age group >70 years	15 (14.0%)
Male sex	63 (58.9%)
Female sex	44 (41.1%)
Diabetes mellitus	48 (44.9%)
Hypertension	52 (48.6%)
Coronary artery disease	21 (19.6%)
Chronic lung disease	17 (15.9%)
Respiratory tract source	38 (35.5%)
Urinary tract source	24 (22.4%)
Gastrointestinal source	18 (16.8%)
Skin/soft tissue source	14 (13.1%)
Bloodstream source	8 (7.5%)
Other source	5 (4.7%)

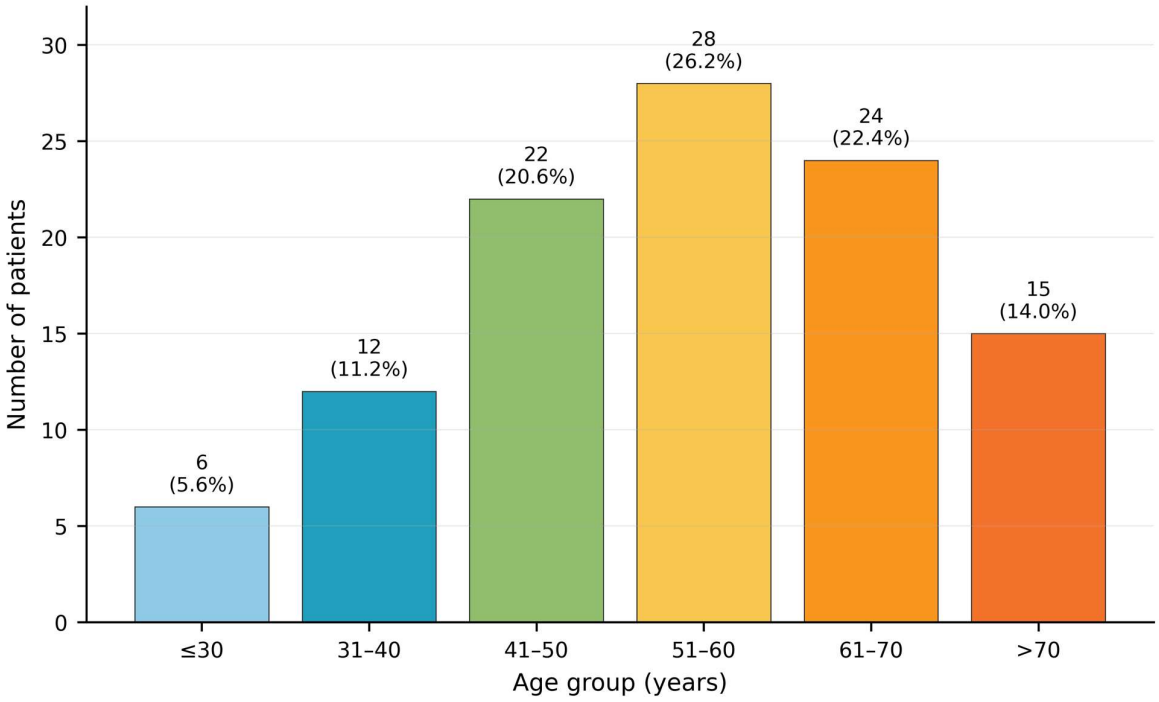

Figure 3: Age distribution of the study population.

Values above bars denote number of patients and percentage within the analysed cohort.

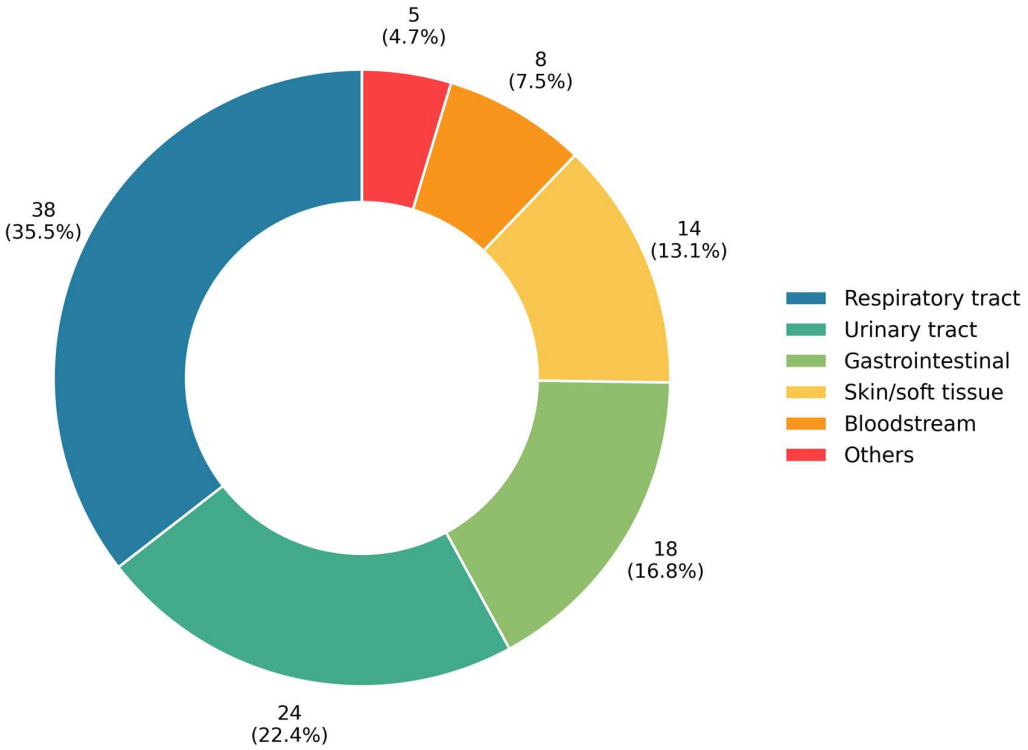

Figure 4: Distribution of sources of infection among patients with sepsis.

HDL-C: high-density lipoprotein cholesterol; percentages are calculated using n=107.

On Day 1, 29 (27.1%) patients had SOFA scores <=5, 51 (47.7%) had scores between 6 and 10, and 27 (25.2%) had scores >10. By Day 5, the proportion with SOFA <=5 increased to 42 (39.3%), while the proportion with SOFA >10 decreased to 24 (22.4%) (Table/Fig 5 and Table/Fig 6).

Table 5. Distribution of SOFA scores on Day 1 and Day 5 (n=107).

SOFA score range	Day 1 n (%)	Day 5 n (%)
<=5	29 (27.1%)	42 (39.3%)
6-10	51 (47.7%)	41 (38.3%)
>10	27 (25.2%)	24 (22.4%)
Total	107 (100.0%)	107 (100.0%)

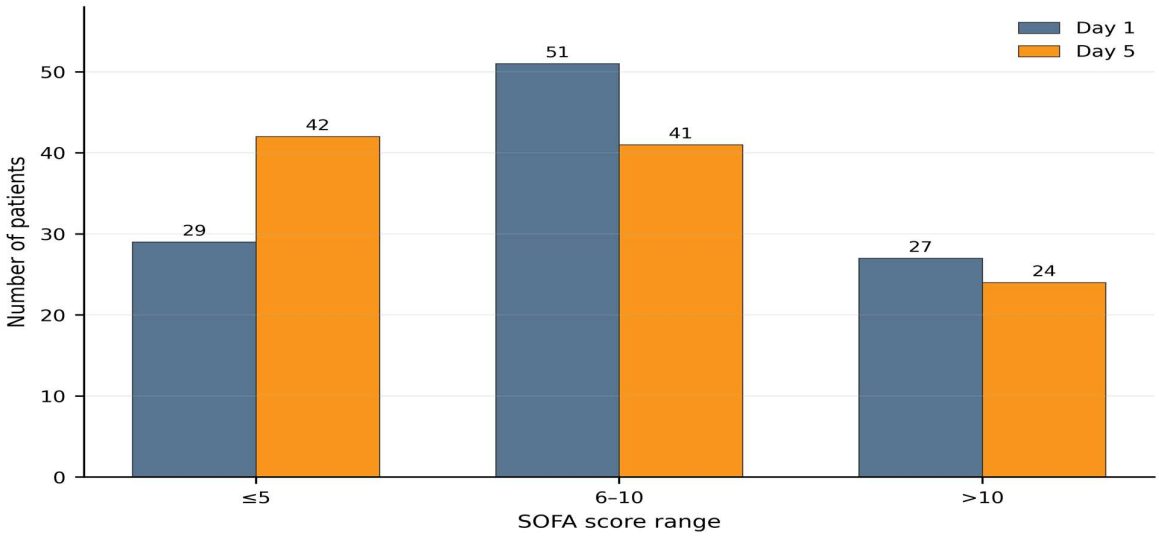

Figure 6: SOFA score distribution on Day 1 and Day 5.

SOFA: Sequential Organ Failure Assessment.

The mean serum HDL-C level was 34.6±8.9 mg/dL on Day 1 and 39.8±9.4 mg/dL on Day 5. HDL-C showed a statistically significant inverse correlation with SOFA score on Day 1 (r=-0.61, p<0.001) and Day 5 (r=-0.66, p<0.001), indicating that lower HDL-C levels were associated with greater organ dysfunction (Table/Fig 7 and Table/Fig 8).

Table 7. Serum HDL-C levels and correlation with SOFA scores.

Parameter	Value	Correlation coefficient	p-value
Mean HDL-C Day 1	34.6±8.9 mg/dL	-	-
Mean HDL-C Day 5	39.8±9.4 mg/dL	-	-
HDL-C Day 1 vs SOFA Day 1	-	r=-0.61	<0.001
HDL-C Day 5 vs SOFA Day 5	-	r=-0.66	<0.001

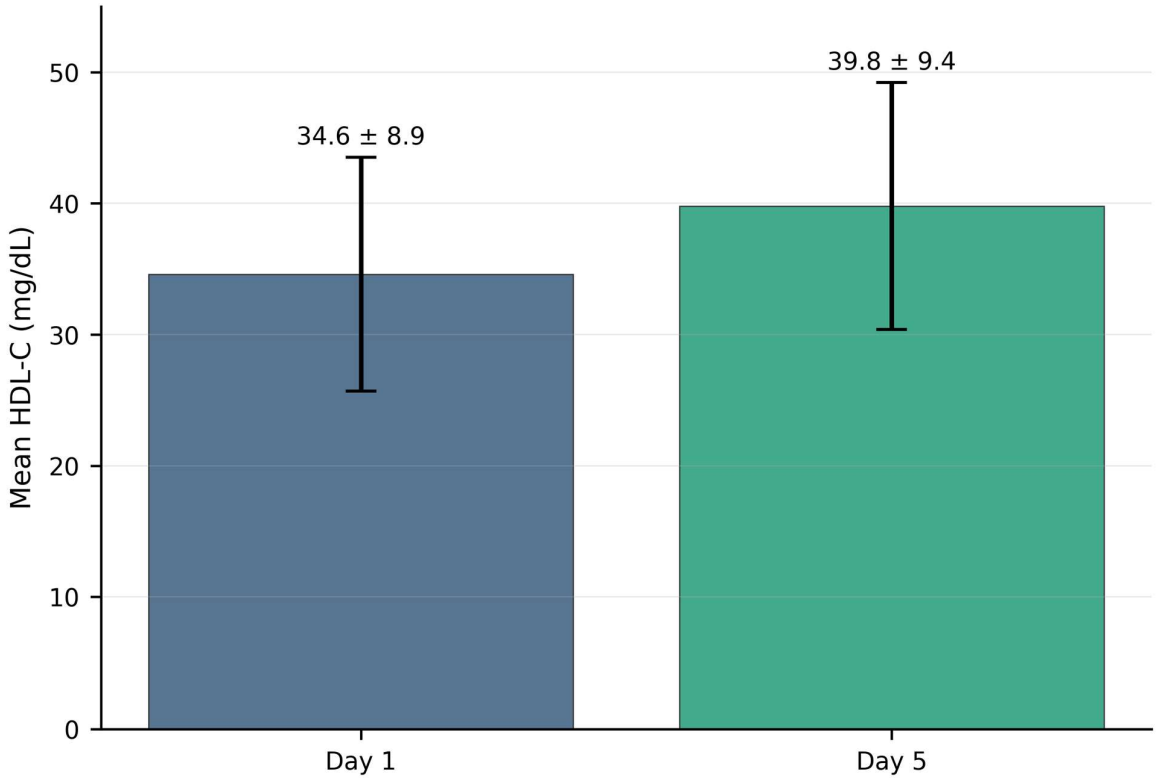

Figure 8: Mean serum HDL-C levels on Day 1 and Day 5.

Error bars represent standard deviation; HDL-C: high-density lipoprotein cholesterol.

Clinical outcome analysis showed that survivors had higher mean HDL-C levels than non-survivors (41.7±7.8 mg/dL vs 28.9±6.5 mg/dL, p<0.001). When HDL-C was dichotomised at 40 mg/dL, non-survivors were concentrated in the <40 mg/dL category. Among patients with HDL-C <40 mg/dL, 22 of 51 died (43.1%), whereas among those with HDL-C >=40 mg/dL, 7 of 56 died (12.5%) (Table/Fig 9 and Table/Fig 10).

Table 9. HDL-C categories and in-hospital outcome.

Outcome/category	n	HDL-C or mortality measure	p-value
Survivors	78	41.7±7.8	-
Non-survivors	29	28.9±6.5	<0.001
HDL-C <40 mg/dL	51	Deaths: 22 (43.1%)	<0.001
HDL-C >=40 mg/dL	56	Deaths: 7 (12.5%)	Reference

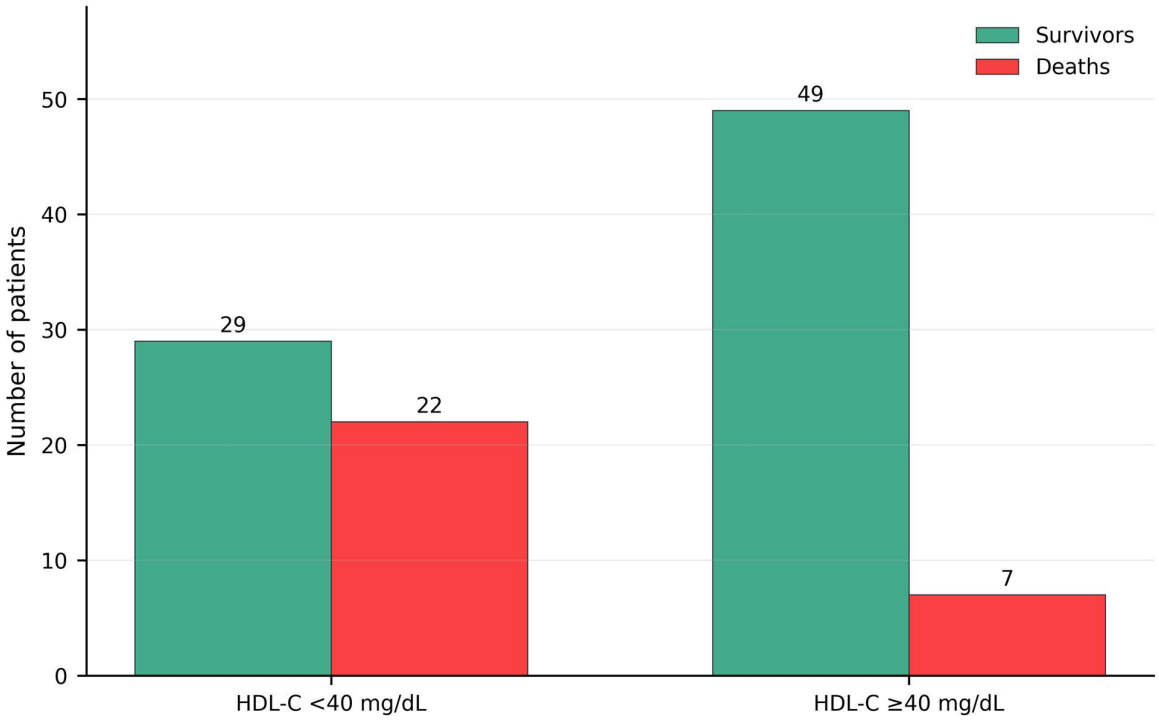

Figure 10: Mortality distribution according to HDL-C category.

HDL-C: high-density lipoprotein cholesterol.

DISCUSSION

This prospective observational study found that lower serum HDL-C levels were associated with more severe organ dysfunction and poorer in-hospital outcome among adults with sepsis. The association was consistent across serial assessment: HDL-C correlated inversely with SOFA score on both Day 1 and Day 5, and non-survivors had markedly lower HDL-C levels than survivors. The finding is clinically relevant because HDL-C is inexpensive, routinely available and easier to repeat than many specialised inflammatory biomarkers.

The study population was largely middle-aged to elderly, with the highest proportion in the 51-60 year age band. This pattern is compatible with the known epidemiology of sepsis, where ageing, immune senescence and reduced physiological reserve increase susceptibility to severe infection and organ dysfunction [14,15]. Indian tertiary-care experience also shows that adult sepsis commonly presents with substantial illness severity and high resource needs [16]. The male predominance observed here mirrors several hospital-based cohorts and may reflect a combination of biological susceptibility, comorbidity burden, occupational exposure, and health-care utilisation patterns in Indian families.

Metabolic and cardiovascular comorbidities were common. Diabetes mellitus and hypertension together formed the dominant background illnesses, a pattern that matters in sepsis because hyperglycaemia, endothelial dysfunction and impaired immune cell function can influence both infection risk and organ injury [17,18]. Diabetes may also interact with lipid metabolism, making interpretation of HDL-C especially pertinent in a cohort where nearly half the patients were diabetic.

Respiratory tract infection was the leading source of sepsis, followed by urinary tract infection. This is consistent with large international ICU cohorts in which pneumonia remains a dominant infectious focus [8]. Indian studies have similarly reported respiratory and urinary sources as frequent contributors, although local organism patterns and antimicrobial resistance may vary by region and referral pathway [16]. In a semi-urban tertiary-care setting such as B.G. Nagara, delayed presentation after community-acquired respiratory infection may partly explain the distribution.

SOFA score distribution showed that most patients had moderate to severe organ dysfunction at admission. The proportion with SOFA scores <=5 increased by Day 5, suggesting clinical stabilisation in a subset, while 22.4% still had SOFA scores >10. Serial SOFA assessment has long been recognised as more informative than a single baseline score because it captures the direction of organ dysfunction during treatment [12,13]. In the present study, the strengthening of the inverse HDL-C-SOFA relationship by Day 5 suggests that persistent HDL-C suppression may be a biochemical signal of unresolved organ dysfunction.

The reduction in HDL-C during sepsis is biologically plausible. HDL particles bind endotoxin, reduce toll-like receptor activation, modulate cytokine release, and protect the vascular endothelium [9,10]. During systemic inflammation, HDL becomes quantitatively depleted and functionally remodelled, with loss of anti-inflammatory and antioxidant properties [9]. Chien et al. reported that low day-1 HDL-C in severe sepsis was associated with increased mortality and adverse outcomes [11]. The present findings move in the same direction.

The mortality difference across the 40 mg/dL HDL-C threshold was striking. Patients below this threshold had a mortality rate of 43.1%, whereas those at or above 40 mg/dL had a mortality rate of 12.5%. Grion et al. similarly found that lipoprotein derangement, including low HDL-C, was associated with severe sepsis risk and adverse outcome [19]. Newer mechanistic work has also linked HDL-C depletion with sepsis-associated organ injury, including acute kidney injury, and has implicated cholesteryl ester transfer protein-mediated HDL remodelling as a possible pathway [20]. These data do not mean that low HDL-C is necessarily causal in every patient, but they support its value as a marker of the host response.

From a bedside perspective, HDL-C is not proposed as a replacement for clinical assessment, lactate, microbiology, haemodynamic monitoring or SOFA scoring. Its value is more realistic as an adjunct. In resource-constrained Indian hospitals

where advanced biomarkers may not be rapidly available, repeated HDL-C estimation could help identify patients who require closer monitoring, especially when low values persist despite treatment. Still, clinical decisions must remain anchored in the full patient picture.

The study has limitations. It was conducted at a single tertiary-care institution, which limits external generalisability. The sample size was modest, and the observational design cannot establish causality between HDL-C depletion and mortality. HDL function, apolipoprotein A-I, inflammatory cytokines and detailed microbiological subgroup outcomes were not assessed. The study evaluated in-hospital outcome only, and longer follow-up after discharge was not available. These limitations should be considered while interpreting the prognostic strength of HDL-C.

CONCLUSION

Serum HDL-C levels were significantly lower among patients with higher SOFA scores and among non-survivors. Mortality was substantially greater when HDL-C was below 40 mg/dL. In adults with sepsis, HDL-C may therefore serve as a simple, inexpensive adjunctive biomarker for prognostic stratification when interpreted alongside serial SOFA assessment and clinical judgement.

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